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Assessment of the RAH-66 Comanche Pilot-Crew Station Interface for the Force Development Test and Experimentation I (FDTE I)

David B. Durbin, Thomas J. Havir, Joshua S. Kennedy, and Regina A. Pomranky

ARL-TR-3027 **September 2003**

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REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT DATE	3. DATES COVERED (From - To)
September 2003	Final	

4. TITLE AND SUBTITLE

Assessment of the RAH-66 Comanche Pilot-Crew Station Interface for the Force Development Test and Experimentation I (FDTE I)

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

Durbin, D.B.; Havir, T.J.; Kennedy, J.S.; Pomranky, R.A. (all of ARL)

5d. PROJECT NUMBER

62716AH70

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

U.S. Army Research Laboratory
Human Research & Engineering Directorate
Aberdeen Proving Ground, MD 21005-5425

8. PERFORMING ORGANIZATION REPORT NUMBER

ARL-TR-3027

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

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15. SUBJECT TERMS

pilot workload RAH-66 Comanche simulator sickness situation awareness

16. SECURITY CLASSIFICATION OF			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			David B. Durbin
Unclassified	Unclassified	Unclassified	UL	130	19b. TELEPHONE NUMBER *(Include area code)* 334-255-2069

Standard Form 298 (Rev. 8/98)
Prescribed by ANSI Std. Z39.18

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Acknowledgments

The authors express their appreciation to Dr. David Johnson (U.S. Army Research Institute for the Behavioral and Social Sciences, Fort Rucker, Alabama) for providing helpful information and data about simulator sickness.

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Executive Summary

Crew workload, crew situational awareness, usability characteristics of the crew station controls, displays, and subsystem interface, and simulator sickness were assessed during the RAH-66 Comanche Force Development Test and Experimentation I (FDTE I). Pilots who participated in FDTE I reported that they typically experienced moderate levels of workload and situational awareness during missions. They noted several problems with usability of the controls, displays, and subsystem interface, which should be resolved. Pilots experienced very mild to moderate simulator sickness symptoms during missions. The discomfort they felt did not significantly affect their performance. A panel of subject matter experts observed each mission and reported that the pilots typically experienced moderate levels of workload and low to moderate levels of situational awareness during missions.

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1. Introduction

1.1 Purpose

The reconnaissance attack helicopter (RAH)-66 Comanche Force Development Test and Experimentation I (FDTE I) was conducted from 18 February to 22 March 2002 at Sikorsky Aircraft Company, Stratford, Connecticut. The purpose of FDTE I was to continue the development and validation of RAH-66 Comanche tactics, techniques, and procedures (TTPs), to assess the pilot-crew station interface, and to explore the suitability of the Comanche portable cockpit (CPC) for use during FDTE II. FDTE I was one of a series of tests planned to support the development of the RAH-66 Comanche. Six additional events are scheduled for the program: an electro-optic subsystem user's survey, FDTE II, FDTE III, a limited user test, FDTE IV, and an initial operational test.

The U.S. Army Operational Test Command (USAOTC) and the U.S. Army Training and Doctrine Command (TRADOC) System Manager-Comanche (TSM-C) conducted the FDTE I. In association with USAOTC and TSM-C, the Human Research and Engineering Directorate of the U.S. Army Research Laboratory (ARL) conducted an assessment of the pilot-crew station interface.

1.2 Assessment of the Pilot-Crew Station Interface

To assess the Comanche pilot-crew station interface, ARL evaluated pilot interactions with the crew station displays, controls, and subsystems. The cognitive state of the pilots was also assessed to identify instances in which the pilots judged that the crew station interface imposed a high workload or hindered their situational awareness. An evaluation was performed to determine if the pilots experienced discomfort because of simulator sickness and whether the discomfort distracted them during missions. ARL also assessed the Manpower and Personnel Integration (MANPRINT) measures of performance (MOPs) issues listed in Table 1.

1.3 Assessment of Crew Workload

A common definition of pilot workload is "the integrated mental and physical effort required to satisfy the perceived demands of a specified flight task" (Roscoe, 1985). It is important to assess pilot workload because mission accomplishment is related to the pilots' mental and physical capability to effectively perform their flight and mission tasks. If one or both pilots experience high workload while performing flight and mission tasks, the tasks may be performed ineffectively or abandoned.

Table 1. MANPRINT measures of performance

MOP 2-5-1. Percent of crew errors attributable to induced fatigue or workload.
MOP 2-5-2. Percent of crew ratings that assessed the CPC interface as contributing to excessive workload during flight and mission tasks.
MOP 2-5-3. Percent of crew ratings that assessed the CPC interface as less than adequate for performing flight and mission tasks.
MOP 2-5-4. Percent of crew ratings that assessed the CPC interface as inhibiting the decision-making process during flight and mission tasks.
MOP 2-5-5. Percent of crew ratings that assessed the CPC interface as inhibiting crew and team situation awareness.
MOP 2-5-6. Percent of crew ratings that assessed the CPC interface as inhibiting crew and team coordination tasks.
MOP 2-5-7. Percent of ratings by the Tactical Steering Committee (TSC) that assessed the CPC as inhibiting mission accomplishment.
MOP 2-5-8. Percent of design differences between the CPC and EDS that substantially impacted the performance of flight and mission tasks.
MOP 2-5-9. Frequency distribution of using switches in the Comanche cockpit, by mission.

1.3.1 Bedford Workload Rating Scale (BWRS)

The Bedford Workload Rating Scale (BWRS) (see Appendix A) was used to estimate cognitive workload. The pilots completed the BWRS immediately after each mission. They used the BWRS to rate the level of workload imposed by each of the 41 RAH-66 Comanche Aircrew Training Manual (ATM) tasks (see Appendix B). The ATM tasks were performed to support reconnaissance, security, and attack operations; target management and fire distribution and coordination missions; and movement and communication functions. Forty-one ATM tasks were selected from the complete list of 52 ATM tasks because they were estimated to have the most potential impact on pilot workload.

The BWRS has been extensively used by the military, civil, and commercial aviation communities to estimate pilot workload (Roscoe and Ellis, 1990). It requires pilots to rate the level of workload associated with a task, based on the amount of spare cognitive capacity they feel they possess to perform additional tasks. Spare cognitive capacity is an important commodity for pilots because they are often required to perform several tasks concurrently. For example, pilots must often perform flight tasks and navigation tasks and monitor radios during the same time period. Mission performance is reduced if pilots are task saturated and have little or no spare capacity to perform other tasks. Design of the Comanche pilot-crew station interface should help ensure that pilots can maintain adequate spare workload capacity when performing flight and mission tasks.

1.4 Assessment of Crew Situation Awareness

Situation awareness (SA) can be defined as the pilot's mental model of the current state of the flight and mission environment. A formal definition is "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future" (Endsley, 1988). It is important to assess SA because it has a direct impact on pilot performance. A high level of SA increases the probability of timely and accurate decisions by pilots. Design of the Comanche pilot-crew station interface should ensure that the pilots are able to maintain consistently high levels of SA.

1.4.1 Situation Awareness Rating Technique (SART)

The Situation Awareness Rating Technique (SART) scale (see Appendix C) was used to estimate the level of SA that pilots experienced during missions. The pilots completed the SART immediately after each mission. The SART was developed as an evaluation tool for design of aircrew systems (Taylor, 1989). The SART is composed of three subscales: understanding (U), demand (D), and supply (S). Taylor stated that SA depends on the pilots' understanding (U) (e.g., quality of information they receive), and the difference between the demand (D) (e.g., complexity of mission) on the pilots' resources and supply (S) (e.g., ability to concentrate). When demand exceeds supply, there is a negative effect on understanding and an overall reduction of SA. The formula $SA = U - (D - S)$ is used to derive the overall SART score. The SART is one of the most thoroughly tested rating scales for estimating SA (Endsley, 2000).

1.5 Assessment of the Crew Station Controls, Displays, and Subsystem Interface

The crew station controls, displays, and subsystem interface directly impact crew workload and SA during a mission. Controls and displays that are designed to augment the cognitive and physical abilities of crews will minimize workload, enhance SA, and contribute to successful mission performance. It is important to assess the crew station interface to identify problems that should be resolved.

To identify any problems with usability of the crew station controls, displays, or subsystem interface, the pilots completed a lengthy questionnaire (see Appendix D) at the end of each week. The pilots also assessed the MANPRINT MOPs (see Table 1) developed by ARL and USAOTC (Department of the Army, 2001). The MOPs assessed the suitability of the CPC crew station interface for use during FDTE II.

1.6 Assessment of Simulator Sickness

Simulator sickness has been defined as a condition in which pilots suffer physiological discomfort in the simulator, which is not experienced while they are flying the actual aircraft

(Kennedy, Lilienthal, Berbaum, Baltzley, and McCauley, 1989). It is generally believed that simulator sickness is caused by a mismatch between the sensory information (e.g., acceleration cues) presented by the simulator, and the sensory information presented by the primary aircraft that the pilot operates. When the sensory information presented by the simulator does not match the aircraft, the pilot's nervous system reacts adversely to the sensory mismatch and the pilot begins to experience discomfort. Simulator sickness symptoms include nausea, dizziness, drowsiness, and several other symptoms (Kennedy et al., 1989). It is important to assess simulator sickness because the discomfort felt by pilots can be distracting during missions. Pilot distraction is one of the operational consequences of simulator sickness listed by Crowley (1987). Additionally, the discomfort could influence the levels of workload and SA that the pilots perceived they experienced during a mission.

1.6.1 Simulator Sickness Questionnaire (SSQ)

The Simulator Sickness Questionnaire (SSQ) (see Appendix E) was administered to the pilots to estimate the severity of physiological discomfort that they experienced during missions and to help determine whether they were being distracted by the discomfort. The SSQ (Kennedy, Lane, Berbaum, and Lilienthal, 1993) is a checklist of 16 symptoms. These symptoms are categorized into three subscales: oculomotor (e.g., eye strain, difficulty focusing, blurred vision); disorientation (e.g., dizziness, vertigo); and nausea (e.g., nausea, increased salivation, burping). The pilots' responses on the three subscales are combined to produce a total severity score, which is an indicator of the overall degree of discomfort that the pilots experienced during the mission.

1.7 FDTE I Simulation Overview

The CPC (see Figure 1) and the engineering development simulator (EDS) (see Figure 2) were the simulation devices used to conduct FDTE I. Pilots received four weeks of intensive training before the FDTE I began. The training consisted of classroom instruction and "hands-on" flight training in the CPC and the EDS. The pilots flew the same missions (e.g., route reconnaissance) during training that they later flew during the record trials. The mission scenario was based on battlefield environments simulating those depicted in the Comanche operational mode summary and mission profile (OMS-MP). The scenario was conducted with four types of missions (see Table 2). Each successive mission increased in difficulty in order to impose progressively greater workload on the pilots. Missions 1 and 2 typically required moderate levels of workload to perform, and missions 3 and 4 required higher levels of workload. Each of the four missions was conducted nine or ten times during FDTE I. The pilots performed specific ATM tasks during each mission. Each ATM task had prescribed conditions and standards that both crew members had to meet to help ensure mission accomplishment.

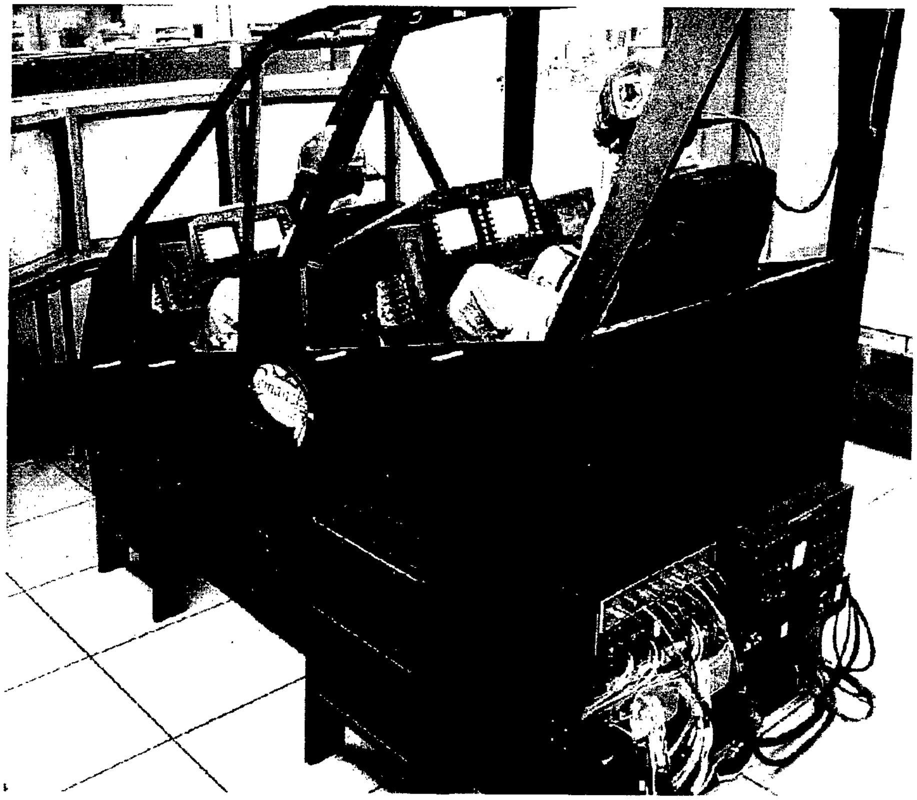

Figure 1. Comanche portable cockpit.

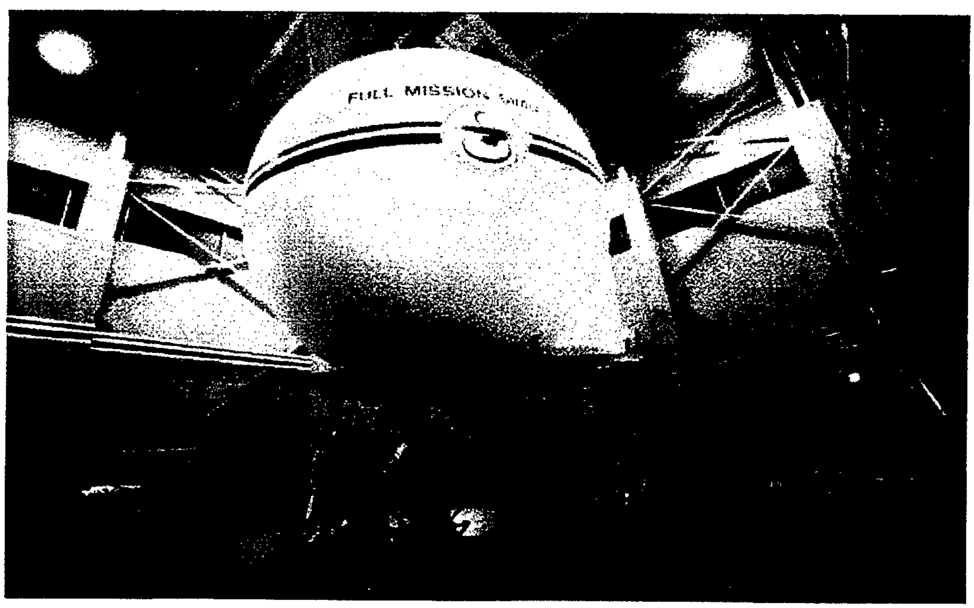

Figure 2. Engineering development simulator.

Table 2. FDTE I missions

Missions	Description	Objectives
1	Conduct ground route reconnaissance Report enemy elements	Navigation, basic mission equipment manipulation, and aircraft control. Complete mission undetected. Report all enemy forces.
2	Conduct route reconnaissance Conduct area reconnaissance Provide security (screen) Engage enemy with artillery	Navigation, advanced mission equipment manipulation, digital communications, and call for fire.
3	Conduct security operations (screen) Conduct deep reconnaissance Attack theater ballistic missiles React to mission change React to inclement weather	All the above plus react to mission changes, and execute procedures for inadvertent entry into instrument meteorological conditions.
4	Conduct zone reconnaissance React to mission change Encounter weather React to aircraft malfunctions	All the above plus react to mission changes

A southwest Asia topographical database was used for the area of operations. A fragmentary order (FRAGO) was issued to initiate each mission. The FRAGOs were based on the Comanche OMS-MP and emphasized crew duties and team tactical employment techniques. The advanced tactical combat (ATCOM) software modules generated threat forces.

The pilots completed 39 missions during FDTE I. For all missions, the pilot who flew the aircraft was assigned to the front seat and the pilot who operated the mission equipment package (MEP) was assigned to the back seat. During the 39 missions, the pilots' seat assignments were varied so that (a) every pilot flew with every other pilot and (b) every pilot occupied the front and rear seats in the CPC and EDS. The factors, controls, and conditions for FDTE I are listed in Table 3.

The pilots used Comanche operational concepts based on the draft TTPs. Emphasis was on individual and crew TTPs within the crew stations as well as team coordination efforts between crew members operating in two separate aircraft. The TTPs addressed the general categories of team movement, target management, fire distribution, coordination, and communication techniques.

Table 3. FDTE I factors, controls, and conditions

Factor	Control	Conditions
Mission	Systematically varied	Route reconnaissance, area reconnaissance, deep reconnaissance and attack, security, zone reconnaissance
Flight profile	Tactically varied	Nap of the earth, contour
Crew response	Tactically varied	Report, engage
Sensor	Tactically varied	Comanche radar, infrared
Scanner	Tactically varied	Continuous, manual
Targets	Tactically varied	BMP, BRDM, T-72, BTR, 2S6, 2S1, SA13, cargo truck, individual soldiers
Friendly forces	Tactically varied	UAV, M1A1, M2-M3, M113, cargo truck, re-fuel HEMTT
Light conditions	Constant	Night
Scenario	Constant	Southwest Asia
Crew	Systematically varied	Maximize pilot combinations
Simulators	Systematically varied	EDS, CPC
Seat position	Systematically varied	Front, rear
Doctrine and tactics	Constant	In accordance with doctrine support package, TRADOC support package, or EOC Comanche TAC SOP
Team organization	Constant	Two RAH-66 Comanches

BMP =Boyevaya Mashina Pehoti, a Soviet mechanized infantry vehicle
BRDM =Boyevaya Razuedyuatael'naya Dozonnaya Meshina, a Soviet vehicle
UAV = unmanned aerial vehicle
HEMTT = heavy expandable mobility tactical truck
EOC = emergency operations center
TAC SOP = tactical standing operating procedure

1.7.1 Tactical Steering Committee

A TSC of subject matter experts (SMEs) observed each mission to (a) develop and refine TTPs and (b) rate crew workload, crew SA, and mission success. The TSC provided an independent assessment of the workload and SA levels experienced by the crew members. They also helped identify instances in which excessive workload and inadequate SA degraded mission effectiveness. The TSC included representatives from the following Army agencies:

- RAH-66 TSM-C, Fort Rucker, Alabama (two pilots)
- USAOTC, Fort Hood, Texas (two pilots)
- Directorate of Training, Doctrine and Simulation, Fort Rucker (one pilot and one civilian)
- Directorate of Combat Developments, Threat Branch, Fort Rucker (one civilian)
- 21st Cavalry Brigade, Fort Hood (one civilian instructor pilot)

TSC members observed each mission using a suite of monitors that showed all crew station displays in the CPC and EDS. TSC members also listened to all audio communications between crew members, aircraft, and the simulated tactical operations center during the missions. A large projection map provided the TSC with a real-time indication of the location of the aircraft, friendly forces, and enemy forces. The TSC conducted an after-action review (AAR) with the pilots at the end of each mission. During the AAR, the TSC reviewed the positive and negative aspects of the mission to (a) provide instruction to the pilots and (b) develop and refine TTPs.

Members of the TSC also discussed with pilots the causes and consequences of workload problems, SA problems, and problems with the pilot-crew station interface.

1.8 RAH-66 Comanche System Description

The RAH-66 Comanche will be a fully integrated, lightweight, twin engine, two-pilot, advanced technology helicopter weapons system designed to project, protect, and sustain the force; to gain information dominance; to shape the battle space; and to conduct decisive operations. System features include lightweight composite airframe structures, protected anti-torque systems, low vibration, high reliability rotor systems, reduced radar cross section (RCS) and infrared (IR) signatures, built-in diagnostics and or prognostics, second generation target acquisition, night vision sensors, and a radar system.

1.9 Comanche Portable Cockpit (CPC) and Engineering Development Simulator (EDS)

The CPC (see Figure 1) and EDS (see Figure 2) each consisted of two crew stations arranged in a tandem seating configuration. The front and rear crew station configurations were identical (see Figure 3), enabling each pilot to perform all ATM tasks. The simulators contained the hardware, MEP, and software that emulated the controls, flight characteristics, and most of the functionality of the proposed Comanche production aircraft. The primary crew station controls and displays were the system management display (SMD), tactical situation display (TSD), cockpit interactive keyboard (CIK), side-arm controller (SAC), collective, and the Kaiser ProView 50[1] head-mounted display (HMD). The EDS was a full motion simulator and the CPC was a fixed base simulator. The motion capability was the only significant difference between the simulators.

1.9.1 System Management Display (SMD) and Tactical Situation Display (TSD)

The SMD is a multi-function color display. In one mode, it provides sensor imagery from the target acquisition system (TAS). In other modes, it provides aircraft subsystem control and status information. The TSD is also a multi-function display. It provides a color map display with superimposed navigational information and symbology depicting the location of threat and friendly forces. Both the SMD and TSD have a bezel incorporating 12 dedicated switches (called mode select keys) in two horizontal rows above and below the display areas. The six mode select keys on the upper bezel of the SMD are used to select communication functions, while the six mode select keys on the lower bezel allow selection of the main menu of the SMD or aircraft and mission subsystems. The six mode select keys on the upper row of the TSD bezel are used to select HMD functions. The six mode select keys on the lower TSD bezel allow manipulation of map modes and display characteristics. Switches in the corners of the bezels are used to adjust screen brightness, symbol brightness, and contrast. There are ten switches in two columns on the right and left of the SMD and TSD. The function and use of these keys vary, depending on the mode that has been selected with the mode selector keys.

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[1] ProView 50™ is a trademark of Kaiser Electro-optics, Inc.

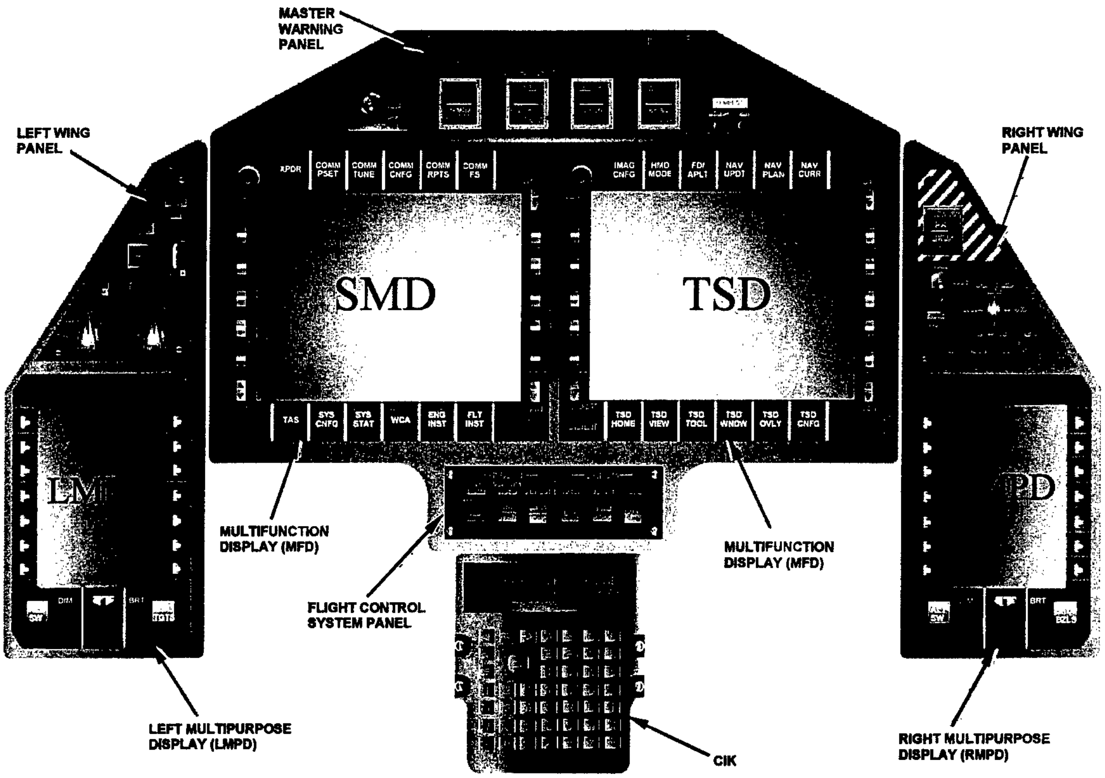

Figure 3. CPC and EDS crew station configuration.

1.9.2 Left and Right Multipurpose Displays (MPDs)

The left MPD (LMPD) is situated outboard of the SMD, and the right MPD (RMPD) is situated outboard of the TSD. The lower segment of the LMPD contains line address keys and the upper segment presents the status of selections made from the tactical interactive annunciator panel (TIAP). The lower segment of the RMPD provides selective monitoring of vehicle subsystems and displays the current settings (frequency, channel preset, transmitter, and ciphony) of the communication radios. The upper segment of the RMPD screen provides information about the operational status and modes of the weapon system and mission equipment.

1.9.3 Collective and Side-arm Controller (SAC)

The collective (see Figure 4) is situated to the left of the crew member's seat and the SAC (see Figure 5) is situated on the right armrest. The SAC allows pilots to control the pitch, roll, and yaw of the aircraft. It also allows 10% authority vertical input. The collective permits full authority vertical input. The collective and SAC grips contain switches that allow hands-on control of critical flight and mission functions.

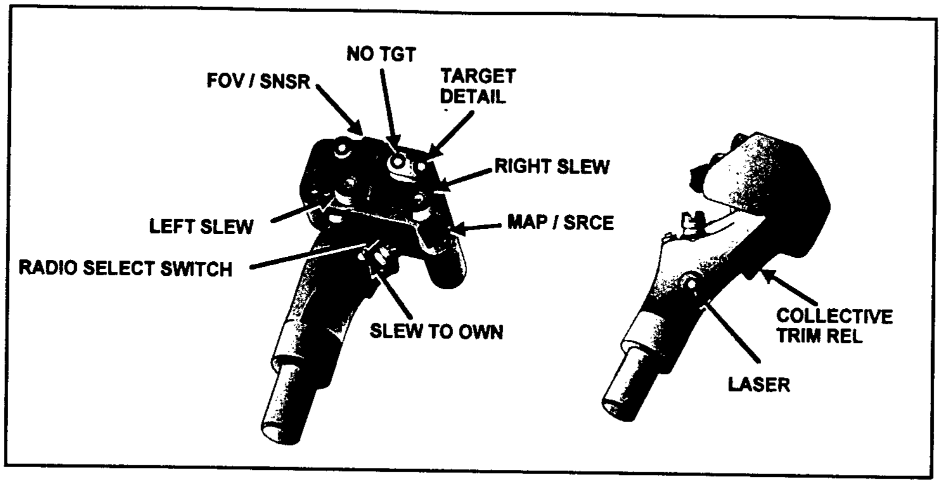

Figure 4. RAH-66 collective.

1.9.4 Cockpit Interactive Keyboard (CIK)

The CIK enables crew members to enter data into the computer system. The data include radio frequencies, coordinates, targets, and text messages.

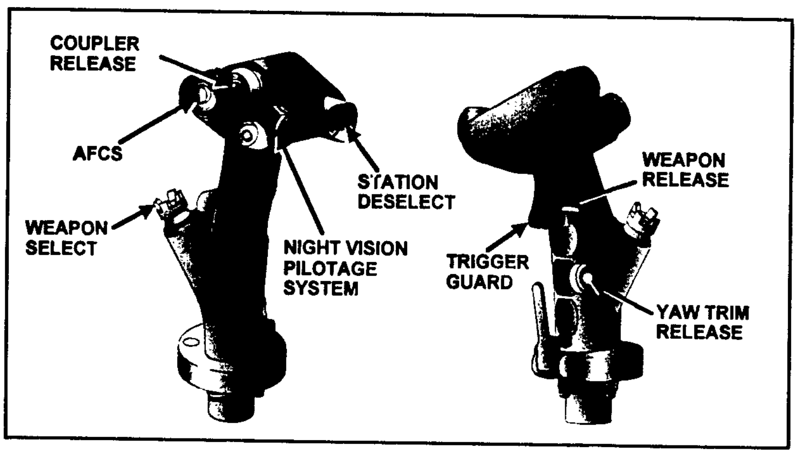

Figure 5. RAH-66 side-arm controller (SAC).

1.9.5 Helmet-Mounted Display (HMD)

The Kaiser ProView 50 (see Figure 6) was the HMD used by all the pilots during FDTE I. It had two liquid crystal displays with a 28° (V) × 49° (H) field of view (FOV) (25% binocular overlap), 1024 × 768 resolution, inter-pupillary distance adjustment, eye relief adjustment, adjustable headband and strap, an electronic control unit, and a Polhemus head-tracking sensor. The HMD weighed 1.3 pounds. The HMD provided the out-the-window (OTW) display to the pilots via a synthetic visual scene overlaid with monochrome symbology. When used in the night vision pilotage system mode, the HMD displayed the forward-looking infrared (FLIR) scene overlaid by the monochrome symbology. A headset was placed over the HMD to provide the pilots with the capability for radio and inter-cockpit communication.

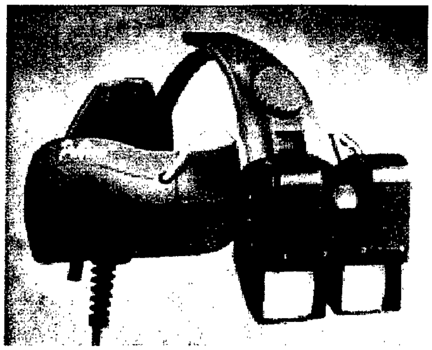

Figure 6. Kaiser ProView 50.

1.9.6 Environmental Conditions in the CPC and EDS Simulators

Ambient noise, light, and temperature levels were recorded during a sample of missions (see Table 4) to identify whether the environmental conditions interfered with pilot performance during missions. Noise and temperature levels in the CPC and EDS were moderate. Light levels in both simulators were low to aid in the use of the Kaiser ProView 50 HMD. The pilots reported that the noise, temperature, and light levels did not distract them, make them uncomfortable, or interfere with the performance of their tasks during missions. Ambient noise was recorded with a 407764 sound level meter made by Extech Instruments Corporation. Ambient light was measured with a Gossen Ultra Pro light meter. Ambient temperature was recorded with a WiBGeT wet bulb globe temperature (WBGT) monitor made by the Imaging and Sensing Technology Corporation.

Table 4. CPC and EDS ambient noise, light, and temperature levels

Simulator	Noise Levels	Light Levels	Temperature Levels
CPC	63 to 67 dBa	0 Lux	68° to 73° F
EDS	72 to 78 dBa	0 to 11 Lux	70° to 74° F

1.9.7 MEP Software

The MEP software used during FDTE I was version 1030. The Flight Director-Autopilot, Navigation Update, and System Status MEP functions were not modeled in software version 10.3 and therefore were not used during FDTE I.

2. Method

2.1 Pilots

Pilots were eight male Army soldiers from the following units: 2-101st and 3-101st Aviation Regiment, Fort Campbell, Kentucky (five pilots), 1-17th Cavalry and 1-82nd Aviation Regiment, Fort Bragg, North Carolina (three pilots). Three soldiers were OH-58D pilots who held the rank of Chief Warrant Officer (CW2). Three soldiers were AH-64D pilots who held the rank of CW2. One soldier was an AH-64D pilot who held the rank of First Lieutenant and one soldier was an AH-64A pilot who held the rank of CW2. They represented a group of low to moderately experienced pilots with total flight hours that ranged from 160 to 650 hours. One of the pilots had participated in the RAH-66 Force Development Experiment 1 (FDE 1) (June 2000) and therefore had previous experience operating a Comanche simulator. Only one of the pilots wore corrective eyewear during missions. The relevant demographic characteristics of the pilots are listed in Table 5.

Table 5. Pilot demographics

	Demographic Characteristics (n = 8)			
	Age (years)	**Flight hours in primary aircraft**	**Total flight hours in Army aircraft***	**Flight hours with night vision devices**
Mean	31	279	415	198
Median	31	228	415	138
Range	24 to 34	10 to 600	160 to 650	30 to 550

*Excludes initial entry training

2.1.1 Pilots' Anthropometric Measurements

Fifteen anthropometric measurements were obtained for each pilot (see Appendix F). The measurements were obtained in accordance with published procedures for measuring Army personnel (Gordon et al., 1989). The upper percentile ranks for male aviators were well represented for 10 of the 15 anthropometric measurements. The measurements were used to assess whether any problems that the pilots experienced when using the crew station controls and displays were related to their body size.

2.2 Data Collection Forms and Procedures

The BWRS, SART, SSQ and controls, displays, and subsystem interface questionnaires (see Appendices C, D, E, and G) were developed in accordance with published guidelines for proper format and content (O'Brien and Charlton, 1996). A pre-test was conducted to refine the questionnaires and to ensure that they could be easily understood and completed by pilots and TSC members.

The pilots and TSC members completed the workload and situation awareness questionnaires immediately after each mission. The pilots completed the SSQ before and after every other mission. At the end of each week of missions, the pilots completed the controls, displays, and subsystem interface questionnaire. Additional data were obtained from the pilots and TSC members during post-mission discussions and the AAR conducted after each mission. Questionnaire results were clarified with information obtained during post-mission discussions and the daily AARs.

2.3 Data Analysis

Pilot responses to the BWRS, SART, SSQ, and controls, displays, and subsystem interface questionnaires were analyzed with means and percentages. Their responses to the BWRS, SART, and SSQ were further analyzed with the Wilcoxon Signed Ranks Test (WSRT) to compare ratings between the pilots when they flew the aircraft versus when they operated the MEP. The WSRT was also used to analyze pilot SSQ ratings when they flew in the EDS versus when they flew in the CPC. Because of the small sample size ($\underline{n} = 8$) of pilots who participated in FDTE I, probability values were computed with Fisher's Exact Test.

2.4 Limitations of Assessment

Limitations included the small sample size of pilots ($\underline{n} = 8$) who participated in FDTE I, their limited experience operating the Comanche simulators, their lack of substantial experience operating Army aircraft and the lack of 100% fidelity between the simulators and the production design of the Comanche aircraft. Additionally, the Flight Director-Autopilot, Navigation Update, and System Status MEP functions were not modeled in the FDTE I software and therefore were not available for the pilots to use during missions. Information and data listed in the Results and Summary sections of this report should be interpreted on the basis of these limitations. Additional data should be collected during future simulations and tests to augment the findings listed in this report.

3. Results

3.1 Crew Workload

3.1.1 Mean Workload Ratings for ATM Tasks

The mean workload ratings listed in Table 6 were derived from the workload ratings provided by the pilots for each ATM task after every mission. The overall mean workload rating provided by the pilots when they flew the aircraft (front seat) was 2.90.

Table 6. Mean workload ratings for ATM tasks

ATM Tasks	Mean Workload		Peak Workload	
	Fly aircraft	Operate MEP	Fly aircraft	Operate MEP
Run-up, hover and before take-off checks	2.29	2.38	2.40	2.48
Maintain air space surveillance	2.62	5.18	3.36	7.32
Radio communications	2.72	2.94	3.36	4.06
Rolling take-off	-----	-----	-----	-----
Visual meteorological conditions (VMC) flight maneuvers	2.74	2.91	3.46	3.52
Electronically aided navigation	2.87	2.89	3.68	3.60
Terrain flight navigation	2.87	3.15	3.54	3.79
Fuel management procedures	3.04	3.06	3.76	3.92
Terrain flight	2.95	3.20	3.98	3.80
Masking and unmasking	2.80	3.07	3.31	3.66
Evasive maneuvers	3.56	3.40	5.09	4.41
Actions on contact	3.21	3.18	4.12	3.95
VMC approach	2.61	-----	3.27	-----
Roll-on landing	2.66	-----	3.00	-----
Inadvertent instrument meteorological conditions (IMC) procedures	2.90	3.38	3.98	4.33
Unusual attitude recovery	-----	-----	-----	-----
Emergency procedures	3.36	2.89	4.07	3.41
TSD operations	2.95	3.19	3.79	4.29
Firing techniques	2.91	3.07	3.57	3.85
Firing position operations	2.85	3.03	3.42	3.79
Helmet-integrated displaying sighting system (HIDSS) operations	2.77	2.97	3.48	3.41
Electro-optic target acquisition and designation system (EOTADS) sensor operations	2.90	3.27	3.93	4.59
Digital communications	2.96	3.18	3.67	4.75
Fire control radar (FCR) operations	2.93	2.91	3.40	4.01
Data entry procedures	4.05	4.24	6.56	6.41
Data management procedures	3.00	2.83	3.68	3.82
Engage target with Point Target Weapon System (PTWS) (Hellfire)	2.98	2.96	3.40	3.92
Engage target with the AWS (20 mm)	3.16	3.81	3.89	4.52
Multi-ship operations	2.71	2.91	3.58	3.64
Security mission	2.85	2.89	3.36	3.52
Aerial observation	2.90	3.00	3.58	3.78
Area reconnaissance	2.89	3.02	3.60	3.73
Route reconnaissance	3.01	3.15	3.89	3.75
Zone reconnaissance	2.95	3.06	3.88	4.02
Digital artillery mission	2.71	2.67	3.04	3.19
Digital remote semi-active laser (SAL) missile mission	3.00	3.25	4.80	5.50
Transmit tactical reports	2.71	2.79	3.36	3.66
Identify major U.S.-Allied equipment	2.51	2.48	2.72	2.72
Identify major threat equipment	2.58	2.58	3.06	3.04
Operate aircraft survivability equipment	2.60	2.58	3.01	2.76
Operate night vision pilotage system	2.71	2.64	3.29	2.87
Overall Workload Ratings	2.90	3.08	3.65	3.92
SD	0.29	0.49	0.68	0.92

The range of mean workload ratings for the ATM tasks was 2.29 to 4.05. The overall mean workload rating provided by the pilots when they operated the MEP (back seat) was 3.08. The range of mean workload ratings for the ATM tasks was 2.38 to 5.18. The difference in overall mean workload ratings between flying the aircraft and operating the MEP was statistically significant (WSRT, $\underline{z} = -2.36, p < .01$). Although the difference was statistically significant, it likely does not reflect an operationally significant difference in spare cognitive capacity because both ratings were close to "3" on the Bedford scale. In summary, the pilots reported that they

- experienced tolerable workload levels when they performed each ATM task;
- did not experience a reduction in spare workload capacity when they performed most ATM tasks

3.1.2 Mean Workload Ratings for Flying the Aircraft

When they flew the aircraft, the pilots reported that they typically did not experience a reduction in spare workload capacity when they performed 37 of 39 ATM tasks (the pilots did not perform 2 of the 41 ATM tasks when they flew the aircraft during FDTE I). The two tasks for which they reported a reduction in spare workload capacity were

- Evasive Maneuvers (mean rating = 3.56)
- Data Entry Procedures (mean rating = 4.05)

The task of performing "evasive maneuvers" received higher ratings because all of the pilot's effort was required to evade a threat or obstacle. Additionally, the OTW view and crew station displays were momentarily blanked (1 to 2 seconds) when the aircraft was hit by ground fire. Blanking of the OTW view and the crew station displays was a simulator artifact that indicated to the crew members that they were being engaged by the threat. Momentarily losing the OTW view and the crew station displays increased the pilots' level of frustration and their perceived workload because they had to spend additional time regaining SA when their OTW view and the displays reappeared. The task of "data entry" received higher ratings because of usability problems with the CIK (see Table 14).

3.1.3 Mean Workload Ratings for Operating the MEP

When operating the MEP, the pilots reported that they typically did not experience a reduction in spare workload capacity when they performed 34 of 37 ATM tasks (the pilots did not perform 4 of the 41 ATM tasks when they operated the MEP during FDTE I). The three tasks for which they reported a reduction in spare workload capacity were

- Engaging Targets with the Area Weapon System (AWS) (mean rating = 3.81)
- Data Entry Procedures (mean rating = 4.24)
- Maintaining Air Space Surveillance (mean rating = 5.18)

The task of "engaging targets with the AWS" received higher ratings because when the pilots fired the gun, it often had no effect on the targets. This problem was usually caused by a simulator malfunction and increased the pilots' frustration and their perceived level of workload.

The task of "data entry procedures" received higher ratings because of usability problems with the CIK. The pilots stated that the CIK was difficult and time consuming to use, kept their heads down in the crew station for extended periods of time, and forced them to lose SA. The task of "maintaining air space surveillance" received higher ratings because the pilots operating the MEP did not have a night vision device that enabled them to see outside the crew station at night while conducting a scan with the TAS. Pilots often conducted continuous scans with the TAS, which prevented them from seeing outside the crew station for extended periods of time. This task was rated as a "10" (on the Bedford Scale) 20 times by the pilots because they simply could not perform the task during long periods of the mission. Thus, the mean workload rating for this task is not a valid measure of workload that the pilots experienced. Rather, the mean workload rating represents the pilots' intent to emphasize that they were frustrated by the lack of equipment needed to perform this task. The production design of the Comanche does not include provisions for a night vision device to allow pilots to see outside the crew station at night while they are conducting a scan with the TAS.

The pilot who operated the MEP in the back seat of the EDS was also designated as the Air Mission Commander (AMC) for all except one mission during FDTE I. The AMC performed additional tasks (e.g., provided mission revisions to the tactical operations center) besides operating the MEP. However, there was no difference in overall mean workload ratings provided by the pilots when they operated the MEP and performed AMC tasks in the EDS versus when they operated the MEP in the CPC. The overall mean workload rating for pilots when they operated the MEP and performed AMC tasks in the EDS was 3.07. The overall mean workload rating for pilots when they operated the MEP in the CPC was 3.09. This difference in workload ratings was not statistically significant (WSRT, $\underline{z} = -.650, p > .05$). This was surprising because TSC and ARL personnel observed that the AMC usually experienced higher workload and had less spare workload capacity during missions than the pilot who operated the MEP in the CPC. When the pilots were asked to explain why they did not rate workload higher for the AMC, most stated that there was not a significant difference in workload when they performed individual ATM tasks and AMC tasks in the EDS versus when they performed individual ATM tasks in the CPC. However, the pilots noted that they typically experienced higher overall levels of workload when they were the AMC because they had to perform more ATM tasks concurrently. Because the pilots provided workload ratings for individual ATM tasks, the ratings did not reflect the higher overall workload that the pilots experienced when they were the AMC and performed several ATM tasks concurrently. To assess the workload that the pilots experienced when they performed several ATM tasks concurrently, they provided the workload ratings listed in Section 3.1.7.

3.1.4 Peak Workload Ratings for ATM Tasks

The pilots provided peak workload ratings to identify any ATM tasks that required a peak workload rating of 6.5 or higher (on the BWRS) to perform. A peak workload rating of 6.5 or higher on the BWRS indicated that the pilots experienced instances when the workload for the task was "not tolerable". Tasks that had mean peak workload ratings of 6.5 or higher provide further justification for improvements that should be made in the crew station design and or aircraft operating procedures to decrease workload for the tasks. As listed in Table 6, the overall mean peak workload rating provided by the pilots when they flew the aircraft was 3.65. The range of mean peak workload ratings was 2.40 to 6.56. The overall mean peak workload rating provided by the pilots when they operated the MEP was 3.92. The range of mean peak workload ratings was 2.48 to 7.32. The difference in mean peak workload ratings between flying the aircraft and operating the MEP was statistically significant (WSRT, $\underline{z} = -2.70$, $p < .05$). However, the practical difference between the ratings is minimal because both ratings are clustered around "4" on the Bedford scale. In summary, the pilots reported that they experienced several instances of high workload that were "not tolerable" for one ATM task when they flew the aircraft and for one ATM task when they operated the MEP.

3.1.5 Mean Peak Workload Ratings When Pilots Flew the Aircraft

The pilots reported that they experienced several instances of workload that were "not tolerable" when they performed

- Data Entry Procedures (mean peak rating = 6.56)

The pilots rated this task as "not tolerable" because of usability problems with the CIK (see Table 14).

3.1.6 Mean Peak Workload Ratings When Pilots Operated the MEP

The pilots reported that they experienced several instances of workload that were "not tolerable" when they performed

- Maintaining Airspace Surveillance (mean peak rating = 7.32)

The pilots reported that they experienced several instances during missions when they could not maintain air space surveillance because there was no night vision device in the back seat. As previously stated, this task was rated as a "10" 20 times by the pilots because they simply could not perform the task for long periods during the mission.

Note that the mean peak workload rating for "data entry procedures" (mean peak rating = 6.41) was very close to being rated "not tolerable". A rating of 6.41 indicated that the pilots experienced several instances when the workload for performing this task was not tolerable because of usability problems with the CIK.

3.1.7 Workload Ratings for Performing Multiple ATM Tasks Concurrently

The workload ratings provided by the pilots helped to identify instances of high workload when they performed individual ATM tasks. To help assess the levels of workload that they experienced when they performed several ATM tasks concurrently, the pilots provided BWRS ratings for periods when they had to "multi-task" (see Table 7). The definition of multi-tasking provided to the pilots by ARL was "periods when you performed several ATM tasks concurrently during missions". The pilots often experienced periods when they had to perform several tasks concurrently within a brief time interval. They provided BWRS ratings for each of the four mission types to help assess multi-tasking for moderate and high intensity missions. The difference in mean ratings between flying the aircraft and operating the MEP was statistically significant for all missions (WSRT, $\underline{z} = -4.31, p < .01$). The difference in multi-tasking ratings between missions 1 and 2 and missions 3 and 4 was statistically significant for pilots when they flew the aircraft (WSRT, $\underline{z} = -3.33, p < .01$). Differences in multi-tasking ratings between missions 1 and 2 and missions 3 and 4 were also statistically significant for the pilots when they operated the MEP (WSRT, $\underline{z} = -3.49, p < .01$).

Table 7. Summary of multi-tasking workload ratings

Missions	Mean Rating When Pilots Flew Aircraft	SD	Mean Rating When Pilots Operated MEP	SD
All Missions	3.65	1.12	4.67	1.37
Missions 1 and 2	2.93	0.73	3.79	1.06
Missions 3 and 4	4.36	1.01	5.54	1.04

When they flew the aircraft and had to perform several tasks concurrently, the pilots reported that they typically had "enough spare capacity for performing additional ATM tasks during moderate intensity missions" (missions 1 and 2). For high intensity missions (missions 3 and 4), the pilots reported that they usually had "insufficient spare capacity for easy attention to additional ATM tasks". When they operated the MEP and had to perform several tasks concurrently, the pilots reported that they typically had "insufficient spare capacity for easy attention to additional ATM tasks" during moderate intensity missions. During high intensity missions, they reported that they usually had "little spare capacity" for performing additional ATM tasks.

3.1.8 TSC Workload Ratings

The TSC rated overall mean workload for flying the aircraft as 3.79 (see Table 8). They rated overall mean workload for operating the MEP as 4.19. The difference in workload ratings was statistically significant (WSRT, $\underline{z} = -2.10, p < .05$). Although the difference was statistically significant, it likely does not reflect an operationally significant difference in spare cognitive capacity because both ratings were close to "4" on the Bedford scale. The mean workload ratings provided by TSC members were higher than those provided by the pilots. The TSC members perceived that the pilots had less spare workload capacity during missions than the pilots perceived they had during missions. TSC members made the observation that the pilots did not experience excessive workload when performing individual ATM tasks, but they were often unable to consistently perform several tasks concurrently (multi-task) during missions. TSC and ARL personnel observed that the pilots often dwelled on one task for a period of time when they should have performed several tasks during the period of time. The inability to consistently perform several tasks concurrently was probably attributable to the limited operational experience of the pilots and the limited time that they had been operating the Comanche simulators. However, the capability to consistently multi-task is important for Comanche pilots and should be closely monitored and carefully assessed during future simulations and tests. Any aspect of the crew station design that induces periods of high workload and reduces the multi-tasking capability of pilots should be identified and improved.

Table 8. Summary of crew and TSC mean workload ratings for all missions

Workload Ratings	Flying the Aircraft	SD	Operating the MEP	SD
Crew Mean Workload Ratings	2.90	0.29	3.08	0.49
Crew Peak Workload Ratings	3.65	0.68	3.92	0.92
Crew Multi-Tasking Ratings	3.65	1.12	4.67	1.37
TSC Mean Workload Ratings	3.79	0.42	4.19	0.28

3.1.9 Transfer of ATM Tasks to the Other Pilot Because of High Workload

During most missions, the pilot who operated the MEP experienced periods of high workload and asked the pilot who flew the aircraft to assist him in performing ATM tasks (see Appendix H). The pilot who operated the MEP typically transferred 5% to 10% of tasks to the pilot who flew the aircraft during missions 1 and 2, 10% to 20% of tasks during mission 3, and 15% to 25% of tasks during mission 4. Sixty-six percent of the tasks transferred to the pilot who flew the aircraft were communication tasks. These tasks included reading and sending digital messages (e.g., spot reports, battle damage assessment reports). Twenty-nine percent of the tasks transferred to the pilot who flew the aircraft were sensor operation tasks (e.g., operating the EOTADS). Five percent of the tasks transferred to the pilot who flew the aircraft were target engagement tasks (e.g., engage targets with the gun).

3.1.10 Comparison of Crew Workload Ratings for FDE 1, FMS 1, and FDTE I

A simulation exercise is a single event that typically does not fully represent the workload that crew members will experience when they operate the aircraft in the field. Variables such as the number of pilots who participated in the simulation, their experience levels, the quantity and quality of the training they received, and differences in the functionality of the simulators versus the aircraft can make it difficult to predict the workload that crew members will experience when they operate the aircraft in the field. Therefore, it is instructive to compare workload results obtained during several simulation exercises. If the workload ratings obtained during several such exercises are similar, the level of confidence that the workload ratings are reliable is increased and may approximate the workload that pilots will experience when operating the aircraft in the field.

Mean overall workload ratings from the Force Development Experiment 1 (FDE 1) (Durbin, 2001), the Sikorsky Full Mission Study 1 (FMS 1) (Cross, 2001) and the FDTE I were compared (see Table 9). The mean overall workload ratings were obtained for 35 ATM tasks during FDE 1, 41 ATM tasks during FDTE I, and 5 mission tasks during FMS 1. As Table 9 depicts, the mean overall workload ratings for pilots when they flew the aircraft were similar across simulation exercises. The mean overall workload ratings for pilots when they operated the MEP were also similar across simulations. The ratings were similar even though there were significant differences in the operational experience levels of the pilots who participated in the simulations. As a group, the eight pilots who participated in FDTE I had relatively low operational experience, the six pilots who participated in FDE 1 had moderate operational experience, and the five pilots who participated in FMS 1 had high levels of operational experience and substantial familiarity with the design of the Comanche crew stations. There were also differences in the method by which the data were collected and differences in the types of missions that were conducted during FDE 1 and FDTE I versus FMS 1. The workload ratings for FDE 1 and FDTE I were obtained immediately after each mission. The workload ratings for FMS 1 were obtained at several "stop" points during each mission. Additionally, the design of the Comanche crew station interface evolved from FDE 1 to FDTE I.

In spite of the differences in crew experience, data collection methodology, types of missions, and maturity of the crew station design, the mean workload ratings were similar across simulations. The mean workload ratings for the simulations were clustered around "3" on the BWRS. A rating of "3" indicates that the pilots perceived that they typically experienced moderate workload levels during the simulations in which they participated. During future simulations and tests, workload data should be collected and compared to FDE 1, FMS 1, and FDTE I.

Table 9. Mean workload ratings for FDE 1, FMS 1, and FDTE I

Simulation Event	Mean Workload Rating When Pilots Flew Aircraft	Mean Workload Rating When Pilots Operated MEP
Force Development Experiment 1	3.18	3.43
Full Mission Study 1	2.48	2.98
Force Development Test and Experimentation 1	2.90	3.08

3.2 Crew Situation Awareness

The overall SART ratings (see Figure 7) indicated that the pilots perceived that they experienced moderate levels of SA when they flew the aircraft and when they operated the MEP.

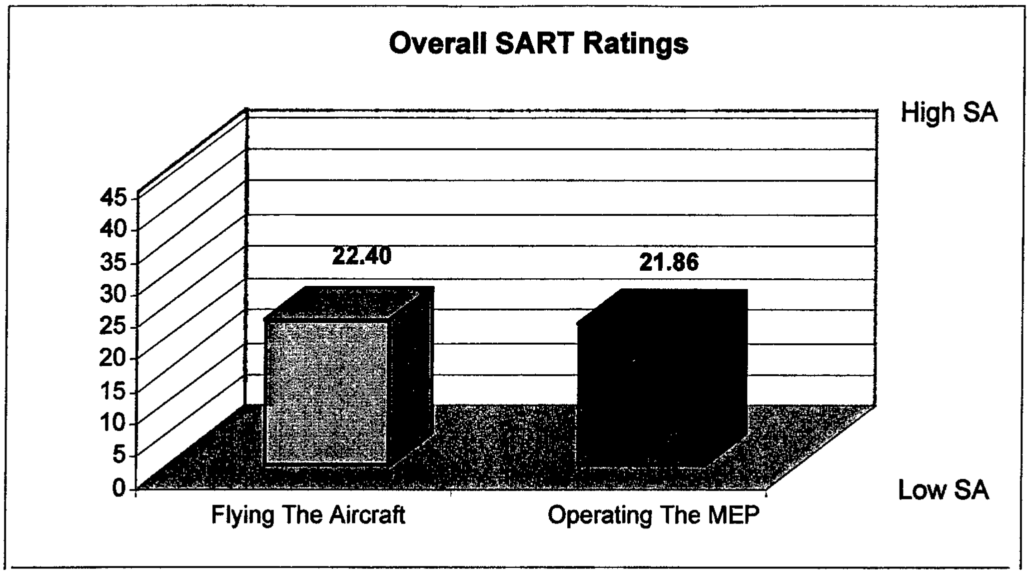

Figure 7. Overall SART ratings for all missions.

Table 10. SART subscale ratings

'Demand' During Missions

Mean Rating When Flying Aircraft 14.03

Low 1-------3-------5-------7-------9-------11-------13-------15-------17-------19-------21 High

Mean Rating When Operating MEP 14.62

'Supply' During Missions

Mean Rating When Flying Aircraft 20.99

Low 1-------4--------7--------10--------13--------16--------19--------21--------24-------27 High

Mean Rating When Operating MEP 20.43

'Understanding' During Missions

Mean Rating When Flying Aircraft 15.44

Low 1-------3-------5-------7-------9-------11-------13-------15-------17-------19-------21 High

Mean Rating When Operating MEP 16.05

Correspondingly, the subscale ratings (see Table 10) indicated that the pilots typically experienced moderate to high levels of "demand," "supply," and "understanding" when they flew the aircraft and when they operated the MEP. In general, the ratings suggest that the pilots felt that they had an adequate supply of cognitive resources to perform the ATM tasks, the cognitive demands on them were not overwhelming, and they had adequate understanding of battlefield elements (e.g., location of threat, status of "ownship") during missions.

3.2.1 SA Ratings for Flying the Aircraft Versus Operating the MEP

The difference in the overall SART ratings between flying the aircraft and operating the MEP for all missions was not statistically significantly (WSRT, $\underline{z} = -.700, p > .05$) (see Table 11). The differences in overall SART ratings for the pilots when they flew the aircraft versus when they operated the MEP (see Table 12) for moderate intensity missions (missions 1 and 2) and higher intensity missions (missions 3 and 4) were not statistically significantly (missions 1 and 2, WSRT, $\underline{z} = -.720, p > .05$, missions 3 and 4, WSRT, $\underline{z} = -.280, p > .05$). However, the difference in ratings for the pilots when they flew the aircraft during moderate intensity missions versus higher intensity missions was statistically significant (WSRT, $\underline{z} = -2.52, p < .01$). The difference in ratings for the pilots when they operated the MEP during moderate intensity missions versus higher intensity missions was also statistically significant (WSRT, $\underline{z} = -2.24, p < .05$). The statistically significant differences in ratings between the moderate intensity missions and higher intensity missions were because of higher ratings on the "demand" subscale for the higher intensity missions.

Table 11. SART subscale ratings for all missions

	Missions 1 through 4	
SART Subscales	**Flying Aircraft**	**Operating MEP**
Demand	14.03	14.62
Instability of Situation	4.85	5.02
Variability of Situation	4.81	4.85
Complexity of Situation	4.37	4.75
Supply	20.99	20.43
Arousal	5.32	5.34
Spare Mental Capacity	5.23	4.92
Concentration	5.36	5.21
Division of Attention	5.08	4.96
Understanding	15.44	16.05
Information Quantity	4.99	5.32
Information Quality	5.01	5.16
Familiarity	5.44	5.57
Mean SART Scores	22.40	21.86
SD	3.70	3.73

Table 12. SART subscale ratings for missions 1 and 2 and missions 3 and 4

	Missions 1 & 2		Missions 3 & 4	
SART Subscales	**Fly aircraft**	**Operate MEP**	**Fly aircraft**	**Operate MEP**
Demand	12.22	12.46	15.95	16.86
Instability of Situation	4.22	4.27	5.48	5.81
Variability of Situation	4.30	4.15	5.39	5.57
Complexity of Situation	3.70	4.04	5.08	5.48
Supply	21.15	20.38	20.90	20.56
Arousal	5.28	5.21	5.38	5.48
Spare Mental Capacity	5.42	5.12	5.05	4.74
Concentration	5.42	5.20	5.32	5.25
Division of Attention	5.03	4.85	5.15	5.09
Understanding	15.77	16.00	15.06	16.14
Information Quantity	5.04	5.23	4.93	5.45
Information Quality	5.10	5.07	4.93	5.25
Familiarity	5.63	5.70	5.20	5.44
Mean SART Scores	24.70	23.93	20.01	19.84
SD	3.98	4.68	3.82	4.01

To understand why the pilots provided similar SA ratings when they flew the aircraft and when they operated the MEP, they were asked to explain the ratings during post-mission discussions with ARL personnel. During these discussions, most pilots stated that when they operated the MEP, they had immediate access to information on the crew station displays, which gave them higher SA of battlefield elements than when they flew the aircraft. However, they reported that workload was somewhat higher when they operated the MEP versus when they flew the aircraft. These two factors (more immediately accessible information but higher workload when operating the MEP) contributed to similar SA ratings.

3.2.2 Problems With SA When Pilots Flew the Aircraft

During post-mission discussions, the pilots reported that the primary factors that limited their SA when they flew the aircraft were (a) the limited FOV of the Kaiser ProView 50 HMD, (b) the lack of high resolution topography (when viewed through the HMD), (c) the limited area of coverage when the 7.2 map scale was used on the TSD, and (d) being engaged by the threat.

3.2.3 Problems With SA When Pilots Operated the MEP

During post-mission discussions, the pilots reported that the primary factors that limited their SA when they operated the MEP were (a) the poor usability characteristics of the CIK, (b) the limited area of coverage when they used the 7.2 map scale on the TSD, and (c) lack of an image intensification (I2) device to monitor the air space around the aircraft.

3.2.4 TSC Ratings of SA

The mean SA rating provided by TSC members (see Table 13) indicated that SA for crew members "needed improvement" and "lack of SA had some negative effect on the success of the mission." During discussions, TSC members stated that the limited operational experience of the pilots was the primary reason that the pilots were unable to maintain high levels of SA. TSC members also stated that the pilots' limited operational experience often led to lack of coordination between aircraft and lack of control of the mission by the AMC.

Table 13. TSC ratings of SA

	TSC SA Ratings	
1	Team was totally aware of all entities on the battlefield.	
2	Team was aware of the battlefield with minor or insignificant variation between perception and reality.	
3	Team was aware of the battlefield. Variation between reality and perception did not significantly impact mission success.	Mean Rating 3.64 (<u>SD</u> = 1.06)
4	SA needs improvement. Lack of SA had some negative effect on the success of the mission.	
5	Lack of SA caused mission failure.	

3.2.5 TSC Mission Success Ratings and Crew SA

At the end of each mission, TSC members rated whether the mission was a success or failure. The criteria that the TSC used to rate mission success or failure was whether the team completed the mission requirements and did not get shot down or crash. The TSC rated 30 of the 39 (77%) missions as "successful" (see Figure 8). They rated 9 of the 39 (23%) missions as "failed." Lack of adequate SA was cited as one of the reasons for failure of most of the nine missions.

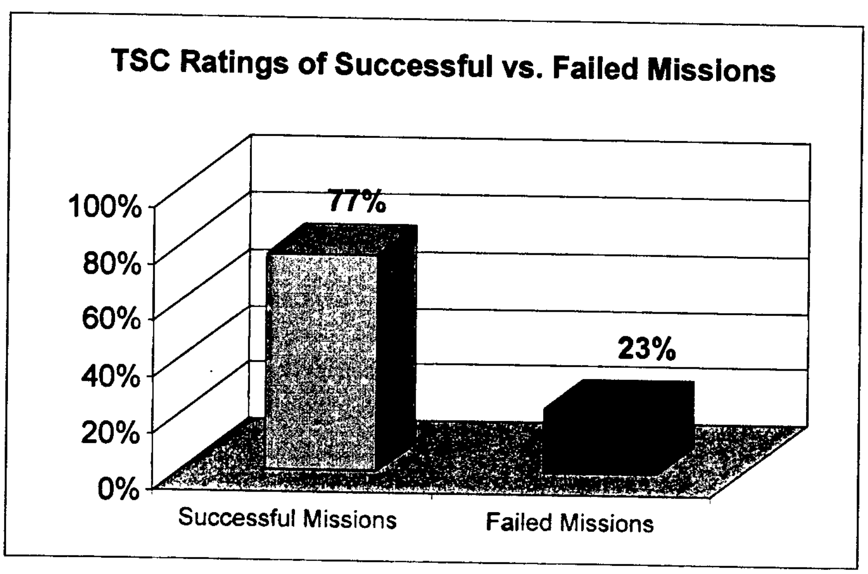

Figure 8. TSC ratings of mission success.

3.3 Usability of Crew Station Controls, Displays, and Subsystem Interface

3.3.1 Positive Aspects of the Crew Station Controls, Displays, and Subsystem Interface

The pilots reported the following positive aspects about the usability of the crew station controls, displays, and subsystem interface (see Appendix I):

- They could typically use the TSD, SMD, FLIR and day television (DTV) in a quick and efficient manner.
- They could quickly navigate through the TSD, SMD, multi-purpose display, and TIAP menu screens.
- They rarely forgot how to navigate through the menu structure on the TSD, SMD, multi-purpose displays, and TIAP.
- They did not have problems using the switches on the side-arm controller while wearing standard flight gloves.

3.3.2 Problems With the Crew Station Controls, Displays, and Subsystem Interface

The primary problems reported by the pilots with the crew station interface are now summarized and listed in Table 14.

All the pilots reported that the usability characteristics of the CIK were very poor. They stated that they experienced high workload when using the CIK; it took them an excessive amount of time to perform several tasks (e.g., sending free text messages), and it decreased their SA. Using the CIK decreased their SA because it was labor intensive to operate and forced them to stay "heads down" in the crew station for extended periods of time.

All the pilots emphatically stated that the MEP operator needs a night vision device so that he could see outside the aircraft at night. During FDTE I, the air crews frequently conducted continuous scans with the TAS, which prevented the MEP operator from having a sensor to see outside the aircraft at night for long periods of time. Therefore, the MEP operator could not help maintain air space surveillance and local security around the aircraft. The pilots reported during post-mission discussions that lack of a night vision device for the MEP operator would reduce the probability of aircraft survivability during training and combat missions because the MEP operator could not help maintain air space surveillance.

All the pilots reported that the heading tape on the HMD should be screen stabilized and should not move, based on aircraft movement. They reported that the heading tape was unreadable and distracting when it moved in their FOV. Three pilots also reported that they occasionally experienced spatial disorientation because of the moving heading tape.

Table 14. Most important crew station design changes recommended by pilots

Component or Function	Required Design Changes
CIK	• Incorporate "TAB" function. • Keyboard layout should be a "QWERTY" configuration. • Need to locate CIK higher in crew station so that pilots can easily shift gaze from CIK to MFDs and outside the crew station. • Need additional default data entries (e.g., grid zone identifier) to decrease time required to enter data into text fields. • Need slew hook, laser, trigger, and scan function controls on CIK. This would provide a centralized location in the crew station for performing tasks with the slew hook, laser, trigger and scan functions. • Need to have text appear on the SMD as it is typed using the CIK (allows pilots to keep their heads up and help maintain SA).
HMD (HIDSS)	• Pilot in back seat needs to have capability (I2) to see outside aircraft at night to help maintain air space surveillance • Heading tape needs to be screen stabilized to enhance readability. • To increase pilot situation awareness of battlefield elements, need the capability to drop an overlay icon in the HMD visual scene.
"No Target" Function	• Need the capability to reacquire a target after it has been "no targeted" ("Recycle Bin" or "Undo" capability).
Collective	• The radio select switch actuation feels the same in each axis that it is moved. This makes it difficult to determine whether you are selecting radios or frequencies. Need more distinctive shape coding of the switch. • The "No Target" button and "Details Button" are too easy to inadvertently actuate because they are close together and similarly shaped. Need to shape code, space further apart, or place a small barrier between the switches to help the pilot easily differentiate between the two switches. • The radio frequency switch and slew-to-own button need to be separated further apart. They are too close together and caused inadvertent changing of radios and frequencies several times during FDTE I.
POIs	• To decrease time required for artillery engagement, need the capability to drop artillery on a POI.
TIAP	• To decrease time required for artillery engagement, need to have the target number appear on the TIAP for all artillery missions. This would allow the pilot to quickly match missions with targets when conducting multiple missions.
Fuel System	• Need to have the aircraft MEP automatically calculate the fuel burn-out time. This capability was not modeled during FDTE I. • Need an alarm that tells the pilot that he has "XX" minutes to "bingo". The "bingo" alarm needs to be associated with a route to the FARP (or other appropriate refueling location), and not a straight line distance to a grid.
	• Need a "ground track display" function on the TSD. This function would assist pilots during recon missions by showing them exactly where the aircraft has flown. It would eliminate confusion about which areas the aircraft has covered

TSD	during the recon mission. • To decrease the time required to plan a route with grids sent via a digital message, the pilot needs to be able to view a digital message and the TSD "Locate" function at the same time. Not being able to view a digital message and the TSD "Locate" function at the same time forces the pilot to write down the grid coordinates he receives via the digital message, close the digital message, open the TSD "Locate" screen and then enter the grids into TSD "Locate". • Need to have a set of preset messages to choose from on the TSD (e.g., spot reports). This would decrease the time required to construct messages.
Scan Information	• To help identify areas that another Comanche has scanned and thereby reduce the time required for reconnaissance, the aircraft need to be able to share scan information. For example, pilots need to be able to transmit "Retain Scan" information to other aircraft.
ASE	• ASE auditory warning should give clock position of threat instead of magnetic degrees heading. This would help pilots to react quicker to threat if ASE warning was clock position (i.e., "laser 2 o"clock"). Still need to have the magnetic heading visually displayed on the TSD.
Remote Hellfire Function	• The "show-on-map" function should slew the TAS onto the target. This would reduce the time required to engage a target with a Hellfire missile. Also, the 30° and 60° safety fans should be dynamic and move with the aircraft.
ATD-C	• Need capability to change a label that has been incorrectly assigned by the ATD-C.
Weapon's Bay Doors	• Need a visual indication that the weapons bay doors are open. This will help prevent the pilot from inadvertently leaving the weapons bay doors open.
TAS	• Need a switch on the sidearm controller to bring up TAS BUPS with only one button push in case of an emergency. • The radar and TAS functions should be separate so that the pilots can operate the sensors independently.
Battle Damage Assessment	• When a target is destroyed, a symbol needs to appear next to the target icon to show that it is destroyed.
EOTADS	• The pilots reported that it was very difficult to manually track objects with the EOTADS when the aircraft was moving because the rate of the slew hook switch was too sensitive. They requested that the rate sensitivity of the slew hook be decreased.

Several times during FDTE I, the pilots accidentally "no targeted" icons (e.g., wingman) on their displays. Because there was no capability for pilots to reacquire icons that they "no targeted," they lost SA of where the icon (e.g., wingman) was situated.

When actuating the radio select switch on the collective, the pilots could not easily determine whether they selected a different radio or selected a pre-set radio frequency. The problem was that the radio select switch position felt the same in each axis for radio select and for radio frequency select. This caused confusion, frequent errors, and increased workload when they intended to select a different radio and inadvertently selected a radio frequency instead (or vice versa).

Several times during FDTE I, the pilots inadvertently pressed the "no target" button when they were trying to press the "details" button (and vice versa). They reported that the problem was attributable to the switches being too close together and similarly shaped. The pilots also reported that the radio frequency switch was too close to the "slew-to-own" button. They occasionally pressed the radio frequency switch when trying to press slew-to-own button.

The FDTE I software did not allow the pilots to perform an artillery "call for fire" directly on a point of interest (POI). The pilots stated that they needed to have this capability in order to minimize the time required to drop artillery on a target. They also stated that the target number for an artillery mission should appear on the TIAP. This would help them keep track of what target the artillery is engaging during multiple missions.

The FDTE I software did not automatically calculate the fuel burn-out time. The pilots stated that they need fuel burn-out time calculated because it would help them know approximately how long they have before needing to return to base or fly to a forward area rearm and refuel point. The pilots also stated that they need an audio alarm that lets them know how much time before they will be at "bingo" fuel.

The pilots stated that planning a route with grids that were sent to them via a digital message was very time consuming because it often took a long time to find the grids on the TSD or use the "locate" function. Also, they could not have the digital message displayed and perform a "locate" function on the multifunction displays at the same time. They requested that a quicker method be developed for planning a route with grids sent via a digital message. To decrease the time required to construct messages, the pilots stated that there should be a set of pre-set messages available to choose from on the TSD (e.g., spot reports).

The pilots occasionally became confused about which areas on the battlefield they had reconnoitered during a mission. They recommended that a ground track display function be implemented on the TSD. The ground track function would show the pilots exactly where the aircraft had flown and would minimize confusion as to which areas they had reconnoitered during the mission.

The pilots were not able to share sensor scan information between the simulators. This inhibited the performance of their team coordination tasks such as providing local security for the other aircraft and conducting overlapping scans during reconnaissance. The pilots recommended that the aircraft be capable of sharing sensor scan information with other aircraft.

To allow pilots to react more quickly to aircraft survivability equipment (ASE) auditory threat warnings, the pilots recommended that the clock position (e.g., 2 o'clock) of the threat be announced to the air crew instead of magnetic degrees heading.

To reduce the time required to engage a threat with a missile, the pilots recommended that the "show-on-map" function should slew the TAS onto the target. To reduce the probability of fratricide or collateral damage, the pilots recommended that the 30° and 60° safety fans should move with the aircraft.

The aided target detection-classification (ATD-C) system occasionally assigned an incorrect label to a target. The pilots stated that they needed the capability to change labels that are incorrectly assigned by the ATD-C.

During FDTE I, the pilots inadvertently left the weapon's bay doors in the "open" position several times. Leaving the weapon's bay doors "open" increased the radar cross section and drag of the aircraft. The pilots recommended that a visual indication be provided on the HIDSS to cue the pilots that the weapon's bay door is in the "open" position.

The pilots recommended that a switch be provided in the crew stations which enables them to quickly display the TAS back-up pilotage system (BUPS) with only one button push during an emergency.

The pilots reported that it was very difficult to manually track with the electro-optic target acquisition and designation system (EOTADS) when the aircraft was moving because the rate of the slew hook switch was too sensitive. They recommended that the rate sensitivity of the slew hook switch be reduced.

To enhance crew SA and help them perform battle damage assessment, the pilots recommended that a symbol appear next to the target, indicating that it has been destroyed.

3.3.3 Anthropometric Accommodation of Pilots

One problem with anthropometric accommodation of the pilots in the CPC and EDS crew stations was noted during FDTE I. The pilot with the largest buttock-knee length (83rd percentile male soldier) and largest crotch height (90th percentile male soldier) measurements reported that his right knee occasionally bumped the side-arm controller during flight. When he bumped the side-arm controller, it caused inadvertent control input. The problem occurred when the pilot placed his feet flat on the floor of the crew station with his lower leg at an approximate 90° angle to the floor. He did not experience a problem when his feet were placed on the footrests. The problem was worse when the aviator wore a kneeboard on his right knee. Even though the dimensions of the CPC and EDS crew stations were not identical to the anticipated design of the production Comanche aircraft, this issue should be evaluated via human figure modeling to determine if it will be a problem with large aviators in the production aircraft.

3.3.4 MOPP Gloves

Each pilot wore mission-oriented protective posture (MOPP) gloves with inserts during one mission. All pilots reported that it was significantly more difficult to actuate crew station switches, buttons, and the trigger guard on the SAC with the MOPP gloves versus standard flight gloves. Pilots with smaller hands had about the same level of difficulty as pilots with larger hands. The comments that the pilots made about the difficulty they experienced while wearing the MOPP gloves are listed in Table 15. Note: One pilot had to return to his unit before the end of FDTE I and did not wear MOPP gloves.

Table 15. Pilot comments about usability problems when they wore MOPP gloves

Pilot Hand Measurements	Pilot Comments
Pilot 1 Hand Breadth 60th % Hand Length 87th % Hand Circumference 80th %	• CIK was hard to manipulate with nuclear, biological, chemical (NBC) gloves along with the hands-on grip (HOG) and SAC switches.
Pilot 2 Hand Breadth 45th % Hand Length 87th % Hand Circumference 69th %	• Unable to rapidly engage targets. Trigger guard was inaccessible with gloves • The warning, caution and advisory (WCA) and slew-to-own buttons were difficult to use with gloves. • Automated flight control system (AFCS) trim and polarity switches (on SAC) were difficult to use with gloves. • The long lever at the base of the SAC made hand movement cumbersome.
Pilot 3 Hand Breadth 14th % Hand Length 87th % Hand Circumference 66th %	• Time to ensure that the right button was selected was doubled with NBC gloves. Could not know if the correct button was selected by feel.
Pilot 4 Hand Breadth 19th % Hand Length 13th % Hand Circumference 5th %	• Trying to raise trigger guard is difficult due to the bulkiness of the glove. • When trying to select gun from the side-arm controller, the bulkiness of the glove pushed the select switch toward the missile. • No target and details switch are pretty much impossible to feel the difference (between the switches) when wearing the gloves.
Pilot 5 Hand Breadth 2nd % Hand Length 71st % Hand Circumference 45th %	• NBC gloves made it impossible to feel buttons. I had to visually search for switches and buttons. Made all tasks slower and more time consuming.
Pilot 6 Hand Breadth 80th % Hand Length 80th % Hand Circumference 90th %	• Difficult to input free text via CIK. • Made it difficult to select only gun. • Accidentally selected missile while trying to select gun. • Kept pressing 'Find Target' button when trying to press 'No Target' button on hands-on grip.
Pilot 7 Hand Breadth 67th % Hand Length 44th % Hand Circumference 74th %	• Gloves caused many difficulties with most all "switchology". • I had significant difficulty with slew hook switches, target find, map scale, zoom, no-target detail, weapons select, etc.

3.4 MANPRINT Measures of Performance (MOPs)

Following is a summary of the pilot responses to the MANPRINT MOPs obtained during post-mission discussions and AARs:

MOP 2-5-1. Percent of crew errors attributable to induced fatigue or workload

The pilots reported that no crew errors were attributable to fatigue and approximately 30% of crew errors were attributable to high workload. The pilots and ARL personnel defined crew errors as mistakes made when they performed the ATM tasks (e.g., misidentification of threat vehicle, fratricide). The pilots stated that most crew errors caused by high workload occurred when they engaged or unexpectedly encountered a threat vehicle.

MOP 2-5-2. Percent of crew ratings that assessed the CPC interface as contributing to excessive workload during flight and mission tasks

The pilots reported that the CPC interface contributed to periods of excessive workload during 100% of the missions. The pilots stated that usability problems with the CIK and the radio select switch on the collective were the biggest contributors to periods of excessive workload in the CPC. Note that the pilots experienced the same usability problems with the CIK and radio select switch on the collective in the EDS.

MOP 2-5-3. Percent of crew ratings that assessed the CPC interface as less than adequate for performing flight and mission tasks

The pilots reported that the overall CPC interface was adequate for performing flight and mission tasks. However, they stated that all the component and function design changes they recommended (see Table 14) should be made to increase the effectiveness of the CPC interface and production aircraft.

MOP 2-5-4. Percent of crew ratings that assessed the CPC interface as inhibiting the decision-making process during flight and mission tasks

The pilots reported that the overall CPC interface did not significantly inhibit the decision-making process during flight and mission tasks. The pilots again reiterated that all the component and function design changes they recommended (see Table 14) need to be made to reduce workload and increase the time they need to make decisions during missions.

MOP 2-5-5. Percent of crew ratings that assessed the CPC interface as inhibiting crew and team situation awareness

The pilots reported that the CPC interface moderately inhibited crew and team SA approximately 30% to 50% of the time during missions. The pilots stated that the primary reasons were lack of an I2 device to monitor the air space around the aircraft when they operated the MEP and the usability problems with the CIK. The CIK limited their SA because it was labor intensive to operate and forced them to stay "heads down" in the crew station for extended periods of time.

Note that the pilots experienced the same problems with the CIK and lack of an I2 device in the EDS.

MOP 2-5-6. Percent of crew ratings that assessed the CPC interface as inhibiting crew and team coordination tasks

The pilots reported that the CPC interface inhibited crew and team coordination tasks approximately 20% to 30% of the time during missions. The pilots stated that the primary reasons were lack of an I2 device to monitor the air space around the aircraft when they operated the MEP and usability problems with the CIK. The CIK limited their crew and team coordination because it caused excessive workload, which decreased the time available to perform crew and team coordination tasks. Note that the pilots experienced the same problems with the CIK and lack of an I2 device in the EDS.

MOP 2-5-7. Percent of ratings by the TSC that assessed the CPC as inhibiting mission accomplishment

The pilots reported that the CPC did not significantly inhibit mission accomplishment. However, they stated that all the component and function design changes they recommended (see Table 14) need to be made to increase the effectiveness of the CPC and production aircraft.

MOP 2-5-8. Percent of design differences between the CPC and EDS that substantially impacted the performance of flight and mission tasks

The pilots reported that the design differences between the CPC and EDS were minimal and did not substantially impact the performance of flight and mission tasks. The only significant difference that the pilots reported between the CPC and EDS was the actuation of the radio select switch on the collective. The radio select switch was oriented differently on the CPC versus EDS collective. The pilots often had trouble remembering which direction to actuate the switch when rotating from one simulator to the other.

MOP 2-5-9. Frequency distribution of using switches in the Comanche cockpit, by mission

The frequency distribution of switch actuations are summarized in Section 3.3.5 and depicted in Figures 9 through 11 and Appendix J.

3.4.1 Switch Actuations by Crew Members During FDTE I

Before FDTE I, the CPC and EDS were instrumented to record all crew station switch actuations made by each pilot during each mission. A total of 254,981 switch actuations were made during the 39 missions (see Appendix J). Sixty-three percent (63%) of the switch actuations were made by the pilots when they operated the MEP, and 37% of the switch actuations were made by the pilots when they flew the aircraft (see Figure 9). Eighty-eight percent (88%) of the switches that were actuated were associated with the communication subsystem (66%) and the TAS (22%) (see Figure 10). The pilots actuated the "XMIT" (Transmit) much more frequently than any other switch. The XMIT switch was actuated 124,055 times which accounted for 49% of all switch actuations. The XMIT switch was situated on the floor of the simulators (foot switch) and was used for talking with the other pilot in the aircraft, the crew in the other Comanche, the TOC, and the ground forces commander.

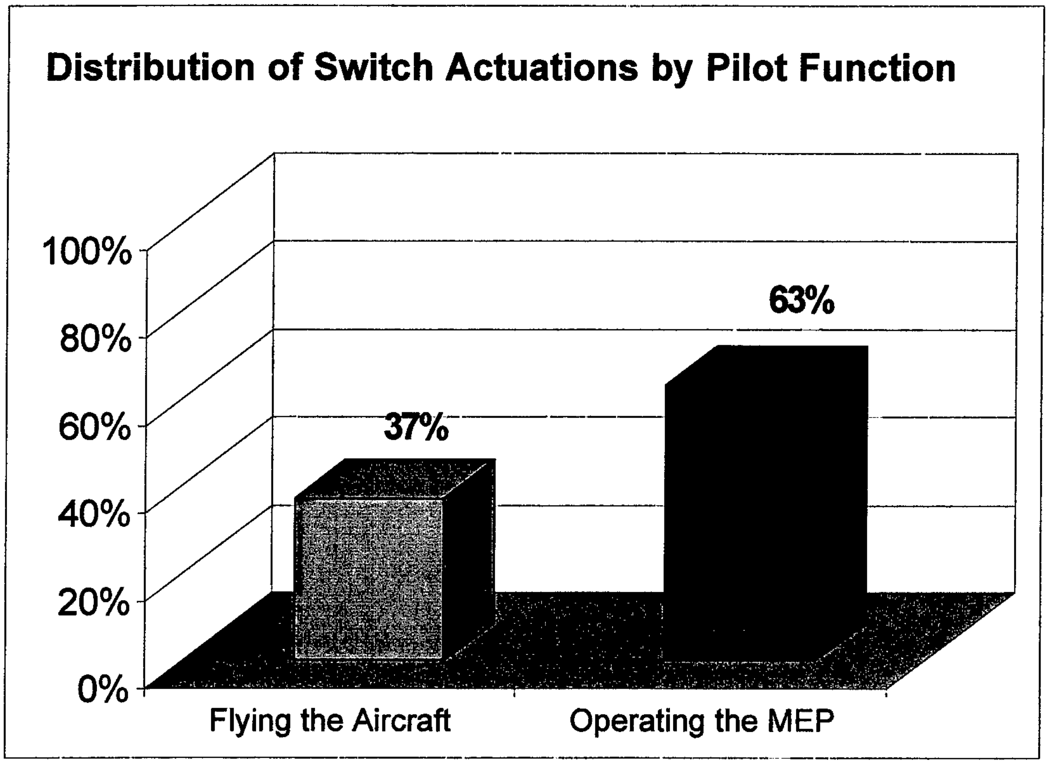

Figure 9. Distribution of switch actuations by pilot function.

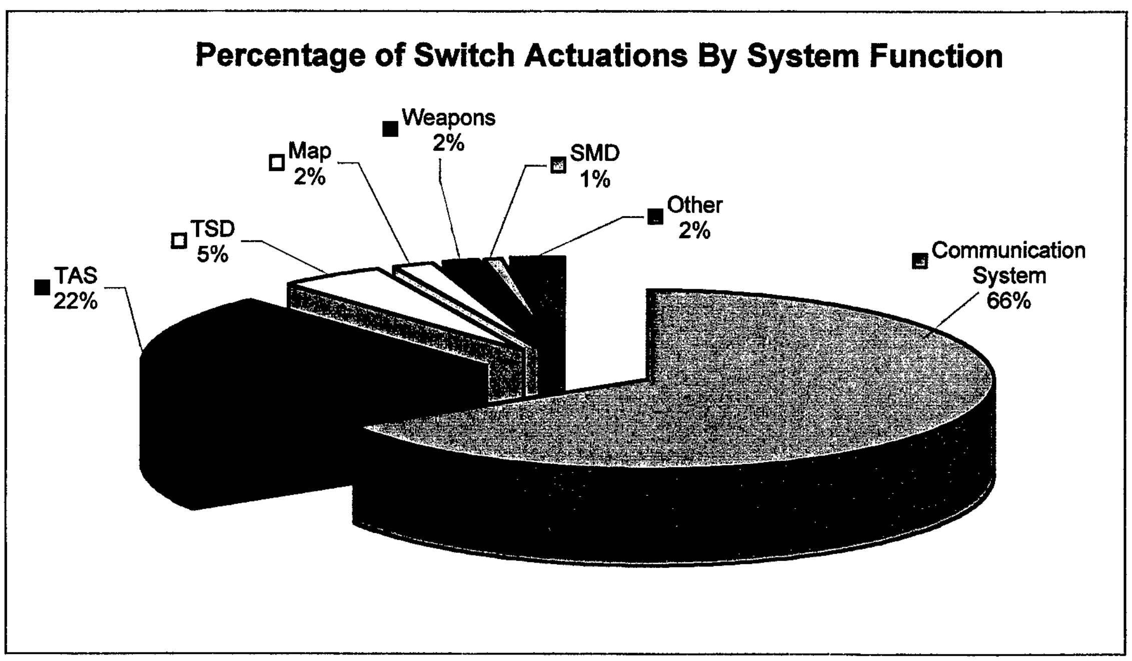

Figure 10. Percentage of switch actuations by system function.

To accurately identify how many switch actuations were made by each pilot during each mission, it was necessary to reduce by 50% the number of switch actuations for transmit on-off, slave on-off, laser on-off and helmet tracking system (HTS) slave on-off. When the pilot depressed these switches to activate a function, one switch actuation was recorded. When the pilot lifted his finger off the switch, another switch actuation was recorded even though he released it within a very short period of time. For the purpose of identifying how many switch actuations the pilots made to activate a function, the total number of switch actuations was 190,372, not 254,981.

During each mission, the pilot operating the MEP made an average of 1,538 switch actuations, and the pilot flying the aircraft made an average 903 switch actuations. Since most missions lasted approximately 90 minutes, the pilot operating the MEP typically made 17 switch actuations per minute or one switch actuation every 3.5 seconds. The pilot flying the aircraft made 10 switch actuations per minute or one switch actuation every 6 seconds. The frequency of switch actuations stayed fairly constant until near the end of the missions (see Figure 11). Near the end of the missions, the number of switch actuations decreased because the pilots had typically completed their objectives and were returning to an assembly area or FARP. Note that the average number of switch actuations made by the pilots every minute provides a general estimate of the frequency of how often they pressed a switch to perform a function. The switch actuations were often clustered within short time intervals (e.g., 30 seconds) and were not evenly spaced over the course of a mission.

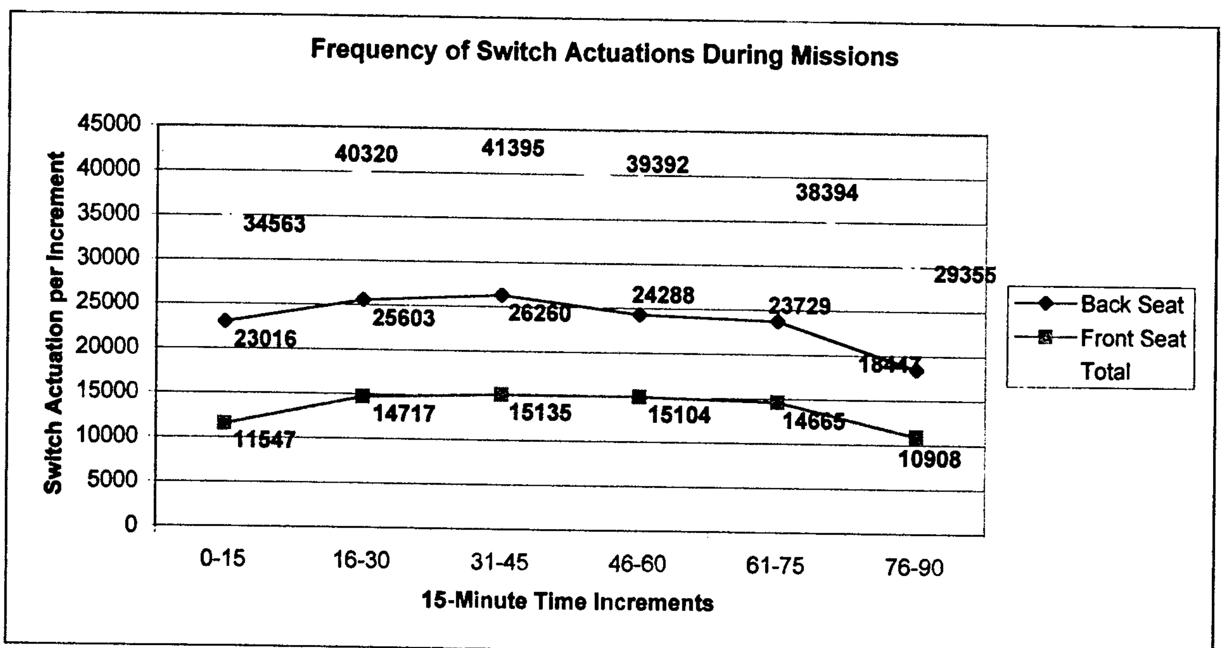

Figure 11. Frequency of switch actuations during missions.

Most of the CIK keypad actuations were not recorded because there was no adequate interface for recording the actuations. The only keypad actuation that was recorded was when pilots pressed the "enter" switch on the CIK. The alphanumeric key presses on the CIK were not recorded. Had they been recorded, the total number of recorded switch actuations would have increased significantly.

The pilots stated that the number of switch actuations they made when they flew the aircraft was typically not excessive and did not induce periods of high workload. When they operated the MEP, the pilots stated that the number of switch actuations typically induced periods of high workload, especially when they had to perform several tasks concurrently. They stated that the number of switch actuations often contributed to keeping them "inside the cockpit" and hindered their ability to maintain awareness of what was happening in the area around the aircraft.

3.5 Simulator Sickness

The pilots reported that they experienced very mild to moderate simulator sickness symptoms during missions. The overall mean total severity score (post mission) for the pilots was 12.62 (see Table 16). The range of mean total severity scores was 2.13 to 32.41. One pilot consistently reported higher SSQ scores than the other pilots. The difference in overall discomfort levels reported by the pilots at the end of the missions compared to the beginning of the missions (pre versus post mission) was statistically significant (WSRT, $\underline{z} = -2.52, p < .01$). However, all the pilots reported during post-mission discussions that the simulator sickness symptoms they experienced did not distract them during missions. While listening to the pilots' conversation during the missions, ARL personnel heard only one discomfort problem occasionally mentioned by the pilots during the 39 missions that they conducted. The discomfort problem was a hot spot on the top of their head from the weight and friction of the Kaiser ProView 50 headset and cable.

Table 16. Simulator sickness questionnaire (SSQ) ratings

Condition	Nausea Subscale	Oculomotor Subscale	Disorientation Subscale	Total Severity Score (Mean)	SD
Pre Mission	2.29	5.83	.90	4.02	3.94
Post Mission	9.54	15.49	4.61	12.62	9.66
EDS	11.84	14.98	4.54	13.25	10.74
CPC	6.73	15.40	4.32	11.40	9.74
Flying Aircraft	8.79	15.94	6.38	13.03	10.84
Operating MEP	10.49	15.13	3.20	12.44	9.15

3.5.1 Comparison of SSQ Scores for the CPC Versus EDS Simulators

The difference in overall discomfort levels that the pilots felt when operating the EDS versus the CPC was not statistically significant (WSRT, $\underline{z} = -.701, p > .10$, ns). However, the mean nausea subscale score was notably higher for pilots when they operated the EDS versus CPC. This was probably because of the motion of the EDS simulator during missions versus no motion in the CPC simulator. The difference in overall discomfort levels that the pilots felt when they flew the aircraft versus when they operated the MEP was not statistically significant (WSRT, $\underline{z} = -.140$, $p > .10$, ns).

3.5.2 Comparison of CPC and EDS SSQ Scores to Other Helicopter Simulators

To assess whether the SSQ ratings provided by the pilots during FDTE I were similar or different to ratings obtained in other helicopter simulators, the mean total severity scores for the EDS and CPC were compared to the mean total severity scores for five other helicopter simulators (see Table 17). The five helicopter simulators were the AH-64A, SH-3H, CH-46E, CH-53D, and CH-56F. These simulators typically induced low to moderate levels of simulator sickness symptoms in pilots.

Table 17. Comparison of CPC and EDS SSQ ratings with SSQ ratings from other helicopter simulators

Simulator	Nausea Subscale	Oculomotor Subscale	Disorientation Subscale	Total Severity Score (Mean)
AH-64A*	-----	-----	-----	25.81
SH-3H	14.70	20.00	12.40	18.80
EDS	11.84	14.98	4.54	13.25
CPC	6.73	15.40	4.32	11.40
CH-53F	7.50	10.50	7.40	10.00
CH-53D	7.20	7.20	4.00	7.50
CH-46E	5.40	7.80	4.50	7.00

*SSQ subscale data not available.

The SSQ scores for the SH-3H, CH-46E, CH-53D, and CH-53F helicopter simulators were obtained from a report by Kennedy, Lane, Berbaum, and Lilienthal (1993). The SSQ scores for the AH-64A simulator were obtained from a report written by Johnson (1997). The SH-3H, CH-46E, CH-53D, and CH-53F helicopter simulators were motion (six degrees of freedom) base simulators with CRT displays that presented the OTW scene to pilots. The AH-64A simulator used hydraulically actuated pneumatic seats to simulate motion. The OTW scene was presented to the AH-64A pilots on a 40-degree horizontal by 30-degree vertical HMD. The physical characteristics of the AH-64A simulator more closely resembled the CPC and EDS than did the physical characteristics of the other simulators listed in Table 17.

The mean total severity score for the five helicopter simulators was 13.82. The mean total severity score for the EDS and CPC was 12.33. Therefore, it can be concluded that the total severity scores for the EDS and CPC were similar to the total severity scores obtained from most of the other helicopters simulators. Based on pilot feedback, their SSQ ratings, and comparison of their SSQ ratings with ratings from other helicopter simulators, it is reasonable to assume that the simulator sickness symptoms they experienced were mild, did not cause them significant discomfort, and did not distract them during missions.

4. Summary

Following is a summary of the results of the assessment of crew workload, crew SA, usability characteristics of the crew station controls, displays, and subsystem interface, MANPRINT MOPs, and simulator sickness data obtained during FDTE I.

4.1 Crew Workload

When they flew the aircraft or operated the MEP, the pilots reported that the workload levels they typically experienced were tolerable when they performed all individual ATM tasks. They reported that they did not experience a reduction in spare workload capacity when they performed most ATM tasks. The pilots reported that the peak workload levels that they typically experienced were tolerable for all but one task when they flew the aircraft and for all but one task when they operated the MEP.

The differences in overall mean and peak workload ratings (for individual ATM tasks) provided by the pilots when they flew the aircraft versus when they operated the MEP were statistically significant. The pilots perceived that the level of workload required to perform individual ATM tasks was higher when they operated the MEP. However, the overall mean and overall peak workload ratings were clustered around the same numerical anchor on the BWRS. This indicated that the pilots did not believe that there was a large disparity in the amount of workload required for performing individual ATM tasks when they flew the aircraft versus when they operated the MEP.

Usability problems with the CIK and the radio select switch on the collective were the main crew station interface problems that contributed to periods of high workload levels for the pilots.

The differences in mean multi-tasking workload ratings provided by the pilots when they flew the aircraft versus when they operated the MEP were statistically significant. The pilots perceived that the level of workload required to perform several tasks concurrently was higher when they operated the MEP. The pilot operating the MEP typically had to perform more tasks concurrently than the pilot flying the aircraft. The pilots reported statistically significant higher workload ratings for high intensity missions versus moderate intensity missions.

The mean overall workload ratings provided by the TSC indicated that they perceived that the pilots typically experienced moderate workload levels during missions. TSC members observed that the pilots were not able to consistently perform several tasks concurrently during missions.

When they operated the MEP, pilots transferred 5% to 25% of their tasks to the pilot who flew the aircraft during periods of high workload. Most tasks that were transferred were communication and sensor operation tasks.

Mean workload ratings provided by the different pilots who participated in the FDE 1, the Sikorsky FMS 1 and the FDTE I simulations were similar. The ratings indicated that the pilots perceived that they typically experienced moderate workload levels during the simulations.

4.2 Crew SA

The SART ratings provided by the pilots indicated that they typically experienced moderate levels of SA during missions when they flew the aircraft and when they operated the MEP. The ratings suggest that the pilots felt that they had an adequate supply of cognitive resources to perform the ATM tasks, the cognitive demands on them were not overwhelming, and they had adequate understanding of battlefield elements (e.g., location of threat, status of ownship) during missions.

The pilots reported that the poor usability of the CIK, the limited area of coverage when they used the 7.2 map scale on the TSD, and lack of an I2 device to monitor the air space around the aircraft when conducting scans with the TAS limited their SA when they operated the MEP. When flying the aircraft, the pilots reported that the limited FOV of the Kaiser ProView 50 HMD, the lack of high resolution topography (when viewed through the HMD), the limited area of coverage when the 7.2 map scale was used on the TSD, and reduced SA when the pilots were being engaged by the threat were the primary factors that limited their SA.

The overall mean SA rating provided by TSC members indicated that SA for crew members "needed improvement" and "lack of SA had some negative effect on the success of the mission." The TSC reported that inadequate SA by the air crews was one reason that 23% of the missions failed during FDTE I. TSC members stated that the limited operational experience of the pilots was the primary reason why they occasionally had low SA.

4.3 Usability of the Crew Station Controls, Displays, and Subsystem Interface

The pilots reported that they were typically able to use the TSD, SMD, FLIR, and DTV in a quick and efficient manner, quickly navigate through the TSD, SMD, multi-purpose displays, and TIAP menu screens, rarely forgot how to navigate through the menu structure on the TSD, SMD, multi-purpose displays, and TIAP, and did not have problems using the switches on the side-arm controller while wearing standard flight gloves.

The pilots experienced usability problems with specific features of the CIK, HMD symbology, "no target function," switches on the collective, POIs, TIAP, fuel system, TSD, ASE auditory warning, remote Hellfire function, ATD-C labeling, lack of a visual indicator for the status of the weapons bay doors, TAS, battle damage assessment (BDA), and EOTADS.

The pilots experienced significant difficulty when actuating crew station switches and buttons and the trigger guard on the SAC with MOPP gloves. The bulkiness of the gloves and lack of adequate tactility made it difficult for the pilots to actuate the crew station switches and buttons and the trigger guard on the SAC during missions.

One pilot reported that his right knee inadvertently bumped the side-arm controller during flight.

4.4 MANPRINT Measures of Performance (MOPs)

No crew errors were attributed to fatigue, and approximately 30% of crew errors were attributed to high workload. Most crew errors caused by high workload occurred when the pilots engaged or unexpectedly encountered a threat vehicle. Usability problems with the CIK and the radio select switch on the collective were the biggest contributors to periods of excessive workload in the CPC. Note that the pilots experienced the same usability problems with the CIK and radio select switch on the collective in the EDS.

The overall CPC interface was adequate for performing flight and mission tasks. The pilots stated that all the component and function design changes they recommended (Table 14) should be made to increase the effectiveness of the CPC interface and production aircraft.

The overall CPC interface did not significantly inhibit the pilots' decision-making process during flight and mission tasks.

The CPC interface moderately inhibited crew and team SA approximately 30% to 50% of the time during missions. The pilots stated that the primary reasons were lack of an I2 device to monitor the air space around the aircraft when they operated the MEP and the usability problems with the CIK. The pilots experienced the same problems with the CIK and lack of an I2 device in the EDS.

The CPC interface inhibited crew and team coordination tasks for 20% to 30% of missions. The pilots stated that the primary reasons were lack of an I2 device to monitor the air space around the aircraft when they operated the MEP and usability problems with the CIK. The pilots experienced the same problems with the CIK and lack of an I2 device in the EDS.

The CPC interface did not significantly inhibit mission accomplishment.

The design differences between the CPC and EDS were minimal and did not substantially impact the performance of flight and mission tasks. The only significant difference that the pilots reported between the CPC and EDS was the orientation and actuation of the radio select switch on the collective.

During each mission, the pilot operating the MEP made an average of 1,538 switch actuations, and the pilot flying the aircraft made an average of 903 switch actuations. Since most missions lasted approximately 90 minutes, the pilot operating the MEP made 17 switch actuations per minute or one switch actuation every 3.5 seconds. The pilot flying the aircraft made 10 switch actuations per minute or one switch actuation every 6 seconds. The pilots stated that the number of switch actuations they made while flying the aircraft was typically not excessive and did not induce periods of high workload. However, they reported that the number of switch actuations they made when operating the MEP occasionally induced periods of high workload and frequently kept them "inside the aircraft." Most of the CIK keypad actuations were not recorded.

Based on the data collected during FDTE I, the CPC appears to be adequate for collecting crew station interface data during FDTE II.

4.5 Simulator Sickness

The pilots reported that they experienced very mild to moderate simulator sickness symptoms during missions. They stated that the discomfort they felt did not distract them during missions. The differences in overall discomfort levels that the pilots felt when they operated the CPC versus the EDS were not statistically significant. The differences in overall discomfort levels that the pilots felt when they flew the aircraft versus when they operated the MEP were also not statistically significant. The SSQ ratings provided by the pilots were similar to ratings obtained from other helicopter simulators.

5. Recommendations

To enhance the pilot-crew station interface and help ensure successful evaluations during future simulations and tests, the following recommendations are made:

- Address and resolve the usability problems that the pilots reported with the controls, displays, and subsystem interface.
- Provide a night vision device to the pilot operating the MEP so that he or she can see outside the cockpit at night when a scan is being conducted with the TAS.
- Investigate methods (e.g., cognitive decision-aiding system) to reduce the number of switch actuations that pilots are required to perform. This would reduce workload for pilots, especially when they have to perform several tasks concurrently.
- Continue to refine the crew station interface to minimize pilot workload and enhance pilot SA.
- Continue to assess the crew station interface during future simulations and tests to evaluate pilot and system performance and assess new functionality that is integrated into the Comanche crew station design.

- If possible, the pilots and TSC members should assess SA using the same scale during future simulations and tests.
- Ensure that pilots who participate in future Comanche simulations and tests possess a wide range of operational experience.

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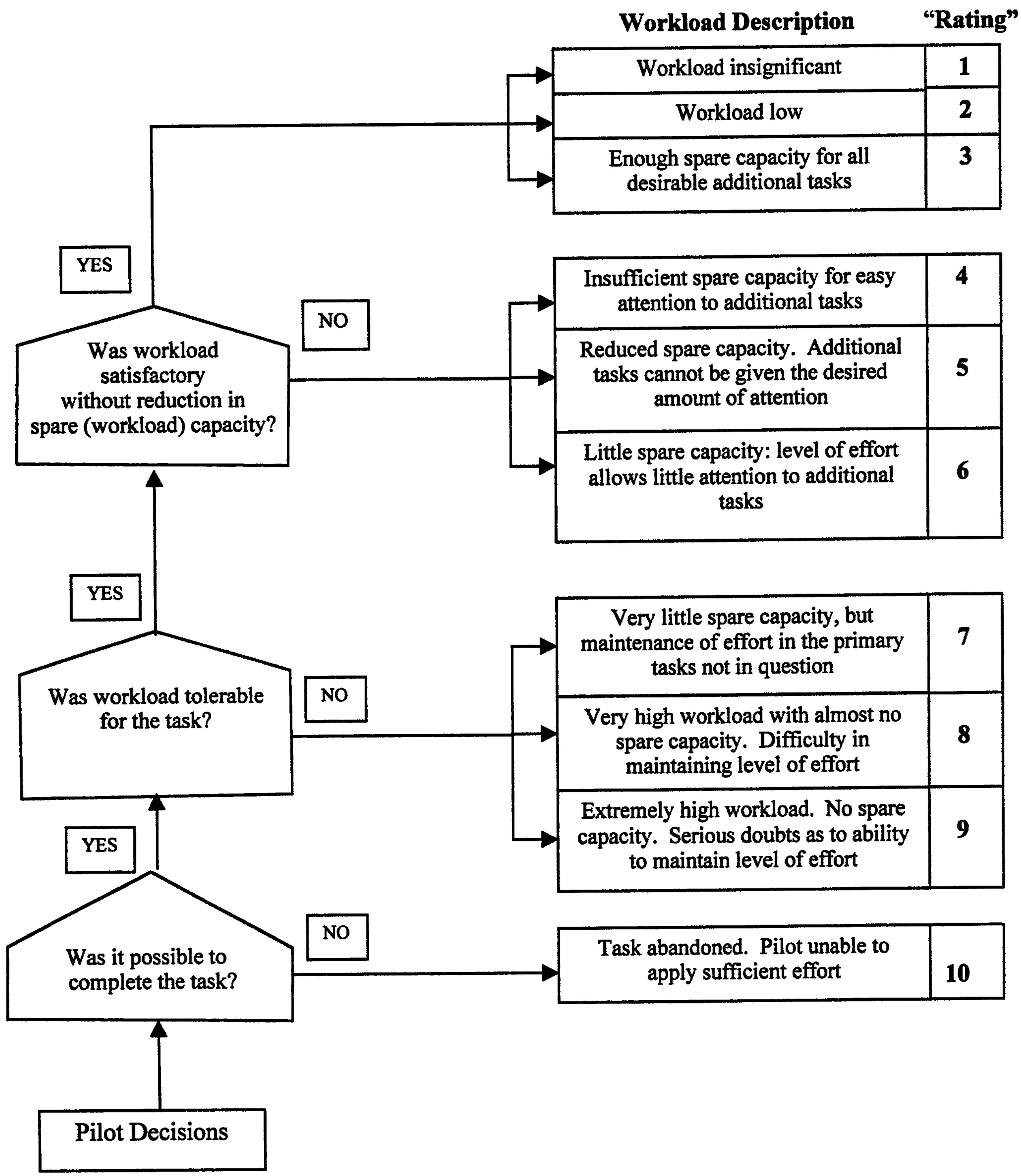
Appendix A. Bedford Workload Rating Scale (BWRS)



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Appendix B. RAH-66 Comanche Aircrew Training Manual (ATM) Tasks

Task No.	Task Title
1007	Perform Run-Up, Hover, and Before Take-off Checks
1042	Maintain Air Space Surveillance
1100	Perform Radio Communications
1114	Perform Rolling Take-off
1117	Perform VMC Flight Maneuvers
1127	Perform Electronically Aided Navigation
1136	Perform Terrain Flight Navigation
1138	Perform Fuel Management Procedures
1146	Perform Terrain Flight
1151	Perform Masking And Unmasking
1153	Perform Evasive Maneuvers
1162	Perform Actions on Contact
1173	Perform VMC Approach
1182	Perform Roll-on Landing
1230	Perform Inadvertent IMC Procedures
1245	Perform Unusual Attitude Recovery
1300	Perform Emergency Procedures
1410	Perform TSD Operations
1422	Perform Firing Techniques
1426	Perform Firing Position Operations
1440	Perform HIDSS Operations
1448	Perform EOTADS Operations
1449	Perform Digital Communications
1451	Perform Fire Control Radar Operations
1454	Perform Data Entry Procedures
1455	Perform Data Management Operations
1458	Engage Target With PTWS (Hellfire)
1464	Engage Target With the AWS (20-mm gun)
2157	Perform Multi-aircraft Operations
2476	Perform Security Mission
2500	Perform Aerial Observation
2502	Perform an Area Reconnaissance
2511	Perform Route Reconnaissance
2514	Perform Zone Reconnaissance
2538	Conduct Digital Artillery Mission
2539	Conduct Digital Remote SAL Missile Mission
2548	Transmit Tactical Reports
2805a	Identify Major United States and Allied Equipment
2805b	Identify Major Threat Equipment
2823	Operate Aircraft Survivability Equipment
2837	Operate Night Vision Pilotage System

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Appendix C. Situation Awareness Rating Technique (SART)

Pin # ____________ Date: ________________

Device: EDS / CPC (Circle one)

Front Seat ______ Back Seat ______ (Check one)

Situation Awareness

SA1. Situation Awareness is defined as "timely knowledge of what is happening as you perform your front or back seat tasks during the mission and understanding of battlefield elements (e.g., location of threat, ownship status)."

Situation Awareness Rating Technique (SART)	
DEMAND	
Instability of Situation	Likeliness of situation to change suddenly
Variability of Situation	Number of variables which require your attention
Complexity of Situation	Degree of complication (number of closely connected parts) of the situation
SUPPLY	
Arousal	Degree to which you are ready for activity
Spare Mental Capacity	Amount of mental ability available to apply to new tasks
Concentration	Degree to which your thoughts are brought to bear on the situation
Division of Attention	Amount of division of your attention in the situation
UNDERSTANDING	
Information Quantity	Amount of knowledge received and understood
Information Quality	Degree of goodness or value of knowledge communicated
Familiarity	Degree of acquaintance with the situation

Rate the level of each component of situation awareness that you had when you performed pilotage tasks in the front seat **–or–** MEP tasks in the back seat during the mission that you just completed. Circle the appropriate number for each component of situation awareness (e.g., complexity of situation).

DEMAND

Instability of situation:	Low	1---------2---------3---------4---------5---------6---------7	High
Variability of situation:	Low	1---------2---------3---------4---------5---------6---------7	High
Complexity of situation:	Low	1---------2---------3---------4---------5---------6---------7	High

---

SUPPLY

Arousal:	Low	1---------2---------3---------4---------5---------6---------7	High
Spare mental capacity:	Low	1---------2---------3---------4---------5---------6---------7	High
Concentration:	Low	1---------2---------3---------4---------5---------6---------7	High
Division of attention:	Low	1---------2---------3---------4---------5---------6---------7	High

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UNDERSTANDING

Information quantity:	Low	1---------2---------3---------4---------5---------6---------7	High
Information quality:	Low	1---------2---------3---------4---------5---------6---------7	High
Familiarity:	Low	1---------2---------3---------4---------5---------6---------7	High

Appendix D. Crew Station Controls, Displays, and Subsystem Interface Questionnaire

Pin # ___________ Phase # _________ Date: _______________________

CREW STATION CONTROLS AND DISPLAYS

The purpose of this questionnaire is to identify any problems that you experienced when using the various crew station components to perform your mission tasks. Your responses should be based only on the problems that you experienced during the Phase that you just completed.

CI1. The following table lists functional components of the TSD and SMD. For each functional component, indicate whether or not you experienced a problem using the component in a quick and efficient manner during the Phase you just completed. Check "Yes" if you experienced one or more problems. Check "No" if you did not experience any problems. Check "Not Used" if you did not use the functional component during the Phase you just completed.

TSD Functional Components	SMD Functional Components
TSD OVERLAY Yes ____ No ____ Not Used ____	SMD COMM FS Yes ____ No ____ Not Used ____
TSD VIEW Yes ____ No ____ Not Used ____	SMD COMM Reports Yes ____ No ____ Not Used ____
TSD TOOLS Yes ____ No ____ Not Used ____	SMD COMM CONFIG Yes ____ No ____ Not Used ____
TSD WINDOWS Yes ____ No ____ Not Used ____	SMD COMM TUNE Yes ____ No ____ Not Used ____
TSD CONFIG Yes ____ No ____ Not Used ____	SMD COMM PSET Yes ____ No ____ Not Used ____

TSD Functional Components	SMD Functional Components
TSD TOOLBAR Yes _____ No _____ Not Used _____	XPNDR Yes _____ No _____ Not Used _____
TSD HOME Yes _____ No _____ Not Used _____	FLT INST Yes _____ No _____ Not Used _____
NAV PLAN Yes _____ No _____ Not Used _____	ENG INST Yes _____ No _____ Not Used _____
NAV CURR Yes _____ No _____ Not Used _____	TAS Yes _____ No _____ Not Used _____
HMD MODE Yes _____ No _____ Not Used _____	WCA Yes _____ No _____ Not Used _____
IMAG CONFIG Yes _____ No _____ Not Used _____	

If you answered "Yes" to any of the questions, describe 1) the problems you experienced, 2) how much the problems degraded your performance during missions, and 3) any recommendations you have for improving the design of the TSD and SMD functional components to correct the problems that you experienced:

____

____

____

____

____

CI2. Indicate whether or not you experienced a problem using the EOTADS Sensor functionality in a quick and efficient manner during the Phase you just completed. Check "Yes" if you experienced one or more problems. Check "No" if you did not experience any problems. Check "Not Used" if you did not use the functional component during the Phase you just completed.

FLIR Operations	Yes _____	No _____	Not Used _____
DTV Operations	Yes _____	No _____	Not Used _____
Tracking Operation	Yes _____	No _____	Not Used _____

If you answered 'Yes' to any of the questions, describe 1) the problems you experienced, 2) how much the problems degraded your performance during missions, and 3) any recommendations you have for improving the design of the EOTADS Sensor functionality to correct the problems that you experienced:

CI3. List and describe any other crew station functions that you were not able to complete in a quick and efficient manner during the Phase you just completed:

____

____

____

____

____

____

CI4. On average, how quickly were you able to navigate through the menu screens on the:

Tactical Situation Display (TSD) (Circle one)

1	2	3	4	5
Very Quickly	Somewhat Quickly	Borderline	Somewhat Slowly	Very Slowly

Systems Management Display (SMD) (Circle one)

1	2	3	4	5
Very Quickly	Somewhat Quickly	Borderline	Somewhat Slowly	Very Slowly

Multipurpose Displays (MPDs) (Circle one)

1	2	3	4	5
Very Quickly	Somewhat Quickly	Borderline	Somewhat Slowly	Very Slowly

Tactical Interface Annunciator Panel (TIAP) (Circle one)

1	2	3	4	5
Very Quickly	Somewhat Quickly	Borderline	Somewhat Slowly	Very Slowly

If you answered "Somewhat Slowly" or "Very Slowly" to any of the questions, list the display, the seat in which you primarily used the display, and why navigation was slow (e.g., "navigating the menu system on the TSD was a slow process due to having to page through several display screens – primarily used the TSD while flying in the front seat").

____

____

____

CI5. How often did you forget the steps required for navigating through the menu screens to accomplish a task?

Tactical Situation Display (TSD) (Circle one)

1	2	3	4
Never	Seldom	Often	Frequently

Systems Management Display (SMD) (Circle one)

1	2	3	4
Never	Seldom	Often	Frequently

Multipurpose Displays (MPDs) (Circle one)

1	2	3	4
Never	Seldom	Often	Frequently

Tactical Interface Annunciator Panel (TIAP) (Circle one)

1	2	3	4
Never	Seldom	Often	Frequently

If you answered "Often" or "Frequently" to any of the questions, list the display, the seat in which you primarily used the display, and the tasks for which you forgot how to navigate through the menu screens (e.g., "I often forgot the steps for navigating through the menu screens on the TSD to perform TSD Toolbar tasks because there are too many steps – primarily used the TSD Toolbar in the back seat").

____

____

____

CI6. Did you have difficulty using any of the switches on the collective grip (e.g., left slew hook) or sidearm controller (e.g., weapon select)?

Collective Grip

Yes _____ No _____

Sidearm Controller

Yes _____ No _____

If you answered 'Yes' to any question, list the switch(es), the seat in which you primarily used the switch(es), and the problem(s) you experienced (e.g., "the right and left slew hook switches on the collective are confusing and time-consuming to use because their shape is identical – primarily used the slew hook switches in the back seat").

____

____

____

CI7. Was there any symbology depicted on the following displays that was difficult to quickly and easily understand?

Head Mounted Display (HMD)

Yes _____ No _____

Systems Management Display (SMD)

Yes _____ No _____

Tactical Situation Display (TSD)

Yes _____ No _____

If yes, explain which symbology was difficult to understand and why:

____

____

____

CI8. Did you experience any problem with dizziness that you think was caused by the motion of the heading tape on the HMD?

Yes _____ No _____

If yes, describe how severe the problem was and how much it degraded your performance:

____

____

____

CI9. Did you experience any problems using the Cockpit Interactive Keyboard (CIK) due to:

a. Location of the CIK Yes _____ No _____

If yes, check the problems that you experienced (check all that apply)

[ ] Data entry required me to lean too far forward
[ ] Other (specify) ____

____

____

b. Layout of CIK keypad (non-QWERTY format) Yes _____ No _____

[ ] Errors in entering data
[ ] Data entry required too much time
[ ] Other (specify) ____

CI10. Were there any significant differences in the operation of the following components in the EDS vs. the CPC?

Cockpit Interactive Keyboard (CIK)

Yes _____ No _____

Multipurpose Displays (MPDs)

Yes _____ No _____

Systems Management Display (SMD)

Yes _____ No _____

Tactical Situation Display (TSD)

Yes _____ No _____

Tactical Interface Annunciator Panel (TIAP)

Yes _____ No _____

Head Mounted Display (HMD)

Yes _____ No _____

Collective Grip

Yes _____ No _____

Sidearm Controller

Yes _____ No _____

If you answered 'Yes' to any of the questions, describe the differences in the EDS vs. CPC and any impact on your performance during missions:

CI11. List any other crew station usability features that hindered your performance during missions:

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Appendix E. Simulator Sickness Questionnaire (SSQ)

Pin #: ________________ Date______________

Device: EDS / CPC (Circle one)

Front Seat _______ Back Seat _______ (Check one)

Symptom Checklist

Instructions: Please indicate the severity of symptoms that apply to you right now by circling the appropriate word.

Symptom	0	1	2	3
General discomfort	None	Slight	Moderate	Severe
Fatigue	None	Slight	Moderate	Severe
Headache	None	Slight	Moderate	Severe
Eyestrain	None	Slight	Moderate	Severe
Difficulty focusing	None	Slight	Moderate	Severe
Increased salivation	None	Slight	Moderate	Severe
Sweating	None	Slight	Moderate	Severe
Nausea	None	Slight	Moderate	Severe
Difficulty concentrating	None	Slight	Moderate	Severe
Fullness of head	None	Slight	Moderate	Severe
Blurred vision	None	Slight	Moderate	Severe
Dizzy (eyes open)	None	Slight	Moderate	Severe
Dizzy (eyes closed)	None	Slight	Moderate	Severe
Vertigo*	None	Slight	Moderate	Severe
Stomach awareness**	None	Slight	Moderate	Severe
Burping	None	Slight	Moderate	Severe

*Vertigo is a loss of orientation with respect to vertical upright.

**Stomach awareness is a feeling of discomfort just short of nausea.

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Appendix F. Summary of Pilot Anthropometric Measurements

	Head Length (cm)	Head Breadth (cm)	Head Circumference (cm)	Inter-pupillary Breadth (cm)	Bitragion Coronal Arc (cm)
Mean	20.0	15.0	57.0	6.2	33.4
SD	.58	.40	1.40	.27	.61
Mean Percentile Rank	65th	39th	57th	24th	7th
Range (percent)	13 to 87	2 to 80	5 to 90	2 to 60	2 to 25

	Eye Height, Sitting (cm)	Crotch Height (cm)	Hand Breadth (cm)	Hand Length (cm)	Hand Circumference (cm)
Mean	81.5	81.9	8.8	19.8	22.0
SD	2.2	3.7	.49	.85	.1.1
Mean Percentile Rank	75th	36th	29th	68th	75th
Range (percent)	36 to 98	8 to 90	1 to 86	25 to 95	28 to 98

	Thumb Breadth (cm)	Thumbtip Reach (cm)	Buttock to Knee Length (cm)	Elbow to Center of Grip Length (cm)	Wrist Center of Grip Length (cm)
Mean	2.3	79.3	61.5	36.9	7.5
SD	.11	3.9	1.72	1.2	.30
Mean Percentile Rank	20th	44th	50th	70th	85th
Range (percent)	6 to 73	14 to 95	23 to 83	39 to 90	55 to 98

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Appendix G. Bedford Workload Rating Scale (BWRS) Questionnaire

Workload

Rate the workload for the Flight and Mission Tasks you performed using the scale provided on the last page of this questionnaire. Place the workload rating in the blank next to each Flight and Mission Task (for BOTH average and peak workload). If you did not perform a task during the mission that you just completed, place an X in the non-applicable (NA) column.

Task No.	Flight and Mission Tasks	Average Workload	Peak Workload	NA
1007	Run-Up, Hover and Before Take-off Checks			
1042	Maintain Air Space Surveillance			
1100	Radio Communications			
1117	VMC Flight Maneuvers			
1127	Electronically Aided Navigation			
1136	Terrain Flight Navigation			
1138	Fuel Management Procedures			
1146	Terrain Flight			
1151	Masking and Unmasking			
1153	Evasive Maneuvers			
1162	Actions on Contact			
1173	VMC Approach			
1182	Roll-on Landing			
1230	Inadvertent IMC Procedures			
1245	Unusual Attitude Recovery			
1300	Emergency Procedures			
1410	TSD Operations			
1422	Firing Techniques			
1426	Firing Position Operations			
1442	HIDSS Operations			
1448	EOTADS Sensor Operations			
1449	Digital Communications			
1451	FCR Operations			
1454	Data Entry Procedures			
1455	Data Management Procedures			
1458	Engage Target with PTWS (Hellfire)			
1464	Engage Target with the AWS (20 mm)			
2157	Multi-ship Operations			
2476	Security Mission			
2500	Aerial Observation			
2502	Area Reconnaissance			
2511	Route Reconnaissance			
2514	Zone Reconnaissance			
2538	Digital Artillery Mission			
2539	Digital Remote SAL Missile Mission			

2548	Transmit Tactical Reports			
2805a	Identify Major US-Allied Equipment			
2805b	Identify Major Threat Equipment			
2823	Operate Aircraft Survivability Equipment			
2837	Operate Night Vision Pilotage System			

If you gave an average or peak workload rating of "6" or higher for any task, write the task number and then explain why the workload was high for the task.

____

____

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____

List any flight and-or mission tasks that you had to ask your crew member to accomplish because your workload was too high:

____

____

____

____

Appendix H. Summary of Crew Workload Comments

ATM Task 1042 - Maintain Air Space Surveillance

Lack of capability for the pilot in the back seat to see outside aircraft at night (49 comments)

- No picture in the back seat to help obstacle avoidance unless stop using TAS.
- No sensor in back to see outside for obstacle avoidance while using TAS.
- No picture in the back seat to help obstacle avoidance (towers). Would like a button to rapidly toggle to BUPS or I2 device in HIDSS.
- Backseat has no pilotage NVS.
- When performing TAS scan, you have no situational awareness.
- Had no visual outside of cockpit when scanning with TAS.
- Could not help maintain surveillance in the back seat because I could not look out while we were evading a target, so I could only say where to go via TSD and not by looking.
- Could not help air space surveillance in the back seat while doing TAS scans.
- Had no pilotage NVS system for the back seat while operating TAS.
- No night vision system, relied on TAS only
- Back seater can't see outside except with TAS.
- As the back-seater, you can't see out the aircraft when using TAS.
- No SA in back seat without I2
- Can't maintain surveillance around helicopter except with TAS
- Back seater operating TAS
- No eyes to complete task when looking in TAS.
- Without I2, very difficult to maintain SA, can't comply with MEPO duties if viewing BUPS.
- No outside reference due to using TAS
- Air space surveillance - you have none when you are in the back seat; all you have is TAS.
- No SA of aircraft flight position when performing MEPO duties.
- No picture in the rear to help with aircraft surveillance when using TAS
- No ability to look outside to fly when using TAS.
- Back seat using EOTADS
- No pilotage NVS in back seat
- Cannot see outside other than with TAS.
- Had no Airspace Surveillance due to EOTADS sensor (when conducting a scan).
- No I2 capability inhibits SA when performing MEPO duties.
- No pilot NVS system in the backseat.
- No sensor to look out when using TAS
- No external vision in back seat due when TAS is operating.
- No sensor to look outside when using TAS.
- Back seat has no visual other than EOTADS.
- Very difficult to visually monitor surveillance as MEPO without I2.
- No NVD for the backseat.
- No surveillance capability except for TAS.
- No sensor in rear to look outside of aircraft for obstacle avoidance when using the TAS.
- No outside visual due to TAS being operated.
- Without I2 in the backseat, you have no SA.

- No NVD system for the back seat.
- Can't maintain aerial surveillance without an I2 device.
- No surveillance outside of aircraft except with TAS.
- No surveillance except for TAS.
- No outside surveillance due to TAS being operated.
- No sensor to look outside for obstacles when using TAS.
- No pilotage NVS system for backseat.
- No pilotage NVS system for the back seat.
- No way for (back seater) to look outside the cockpit when using the TAS.
- No surveillance situational awareness while scanning with TAS.

Other comment

- Couldn't maintain air space surveillance while sending messages.

ATM Task 1100 – Radio Communications

<u>Radio Select Switch is Difficult to Use</u> (eight comments)

- Radio select switch on collective is difficult to use.
- Switch on collective can easily be bumped which switches frequencies on the radio.
- Had to take hands off controls to push two buttons to switch radios instead of using COM switch on HOG.
- Sometimes you inadvertently bump switch and change radios.
- Radio COM switch on collective too small when you need to talk to several people. Changing radio too difficult.
- Radio select switch difficult to use (off ... set-up). I used Eng page to change radios.
- Been using ENG PAGE-LMPD to switch radio because of too many mistakes with radio select switch.
- Radios were tuned wrong once on accident. Makes it difficult to know which frequency you are using when it is so easy to accidentally off-tune.

<u>Radio Volume Level Was Too Low (Simulator Problem)</u> (four comments)

- Could not hear CPC due to low volume.
- Radio volume from CPC to EDS was too low.
- Could not hear CPC radios.
- CPC volume in EDS headset is very low and difficult to hear.
- Radios in CPC and EDS are not working well. Volume is too low from CPC to EDS.

Difficult to Use Radios When Workload Was High (four comments)

- When radio traffic is heavy, workload is high.
- Radios are very busy when you're AMC.
- While engaging targets and trying to talk, I was tasked to the max.
- Didn't have sufficient spare time to disposition multiple targets and understand radio traffic at same time.

Other Problem (one comment)

- Radio switch is different in the EDS versus CPC (actuates differently).

ATM Task 1117 – VMC Flight Maneuvers

- Couldn't easily maintain ground clearance when sending free text.
- Can be difficult to fly terrain flight mode due to poor visuals from simulator.
- Multiple tasks thrown on front seater from back seater who was AMC.

ATM Task 1127 – Electronically Aided Navigation

Difficult to Navigate Because of Size of Map or TSD (five comments)

- SA is low when in TSD in large scale. Makes navigation difficult.
- Should be able to "direct-to" to a point without having to slew all over the map. Should be able to "direct-to" from a list of points.
- Difficult to follow TSD when flying 'off' of map (when scrolling the slew hook to see where we are going).
- Very difficult to navigate to NAIs when they were far away.
- Low SA at times due to size of TSD.

Other Problem (one comment)

- No target of sistership made these tasks harder.

ATM Task 1136 - Terrain Flight Navigation

- In simulation, not enough terrain detail to fly effectively at NOE.

ATM Task 1138 – Fuel Management Procedures

Lack of Fuel Burn-Out Time (25 comments)

- Aircraft doesn't provide burn-out times.
- No endurance calculation for fuel mgmt.
- No endurance burnout time given.
- No endurance time is computed by the system for you.
- No burn-out endurance time is available to the aircrew.
- No burn-out endurance times are computed (for fuel management).
- No endurance time is calculated by the aircraft.
- No burn-out endurance time is computed.
- No burn-out rate is time computed by the aircraft.
- The aircraft does not compute fuel burn-out time.
- No fuel burn-out time is calculated by aircraft.
- No fuel burnout time is computed by the aircraft.
- Fuel check – total attention needed when calculating fuel check. If aircraft gave me a fuel burnout time, I could better judge my fuel state.

- Need a feature to tell fuel burn so far in mission. Difficult since we don't have fuel burn charts or exact maps to do good fuel planning.
- Fuel management procedures should be more automated.
- Fuel management requires devotion to engine page when computing fuel management procedures.
- I have to look on engine page to calculate fuel burn, then calculate on paper the burn-out time.
- All attention is inside.
- Required to use engine page.
- Fuel management – Engine monitor page required total attention while calculating fuel.
- No easy accessible fuel burn rate to observe while conducting mission tasks.
- Fuel burn rate calculation is not readily accessible.
- The aircraft systems don't help you compute, you have to use E6-B to figure burn-out time, etc.
- System doesn't present fuel endurance times.

ATM Task 1146 – Terrain Flight

Simulator Did Not Respond Well to Control Input (three comments)

- Simulator does not respond well to control inputs. Rapid inputs are difficult to control.
- Simulator does not respond well to pilot inputs when beyond minor maneuvers.
- Simulator does not respond to control inputs correctly and low resolution graphics make judging relative motion difficult.

Other Problems (eight comments)

- High speed terrain flight was very taxing on ridgelines because of poor depth perception along ridgelines.
- In simulation, not enough terrain detail to fly effectively at NOE.
- Terrain flight difficult at high speeds because of limited collective authority at higher speeds.
- Difficult to "feel" out of trim situation in simulator.
- Evasive maneuvers at 100 knots at 20 AGL.
- Couldn't easily maintain ground clearance when sending free text.
- Simulator would not hold altitude.
- Trying to maintain NOE through the mountains and minimize exposure caused me to strike the ground twice.

ATM Task 1151 - Masking and Unmasking

- High workload due to actions on contact with 2S6.
- Difficult maneuvering in mountainous terrain and finding a good OP without gaining too much altitude.

ATM Task 1153 – Evasive Maneuvers

HMD Display Blanks When Aircraft is Shot at by the Threat (eight comments)

- HIDSS goes red when aircraft is shot at. Cannot effectively evade with terrain.
- Screen blanks out during evasive maneuvers and controls are not great for yank and bank.
- Difficult to acquire targets when screen blanks while being shot.
- When performing evasive maneuvers and being fired at (by threat), the whole screen blanks and you can't see to evade.
- Red screen is distracting during evasive maneuvers.
- Screen on HMD goes blank when you are shot at.
- Evasive maneuvers require all attention of pilot.
- HMD turns blank when engaged by the threat which results in no visual outside.

High Workload When Performing Evasive Maneuvers (eight comments)

- Actions on contact with evasive maneuvers requires all attention to flying aircraft related systems.
- Was very busy when being tracked by ADA and trying to break lock. Very easy to lose situational awareness when making rapid turns.
- All attention is required to fly aircraft in this manner.
- Flying aircraft requires individual attention when doing other than straight and level.
- Evasive maneuvers very difficult. Need to include in the task to maintain altitude for obstacle avoidance while deploying to cover. It is easy to hit the ground while trying to get away from there.
- Breaking contact with every vehicle requires almost all the attention of the pilot on the controls.
- When breaking contact with enemy, almost all attention is directed to flying the aircraft NOE to a covered position.
- When performing evasive maneuvers, no other tasks can be performed. All attention is focused on maneuvers.

Other Problems (five comments)

- Yank and bank maneuvers difficult to control.
- Poor visual references (sim video) makes task difficult.
- Trying to evade from enemy, the simulator does not represent distinctions between high and low ground soon enough.
- Due to the lack of motion parallax in simulation.
- Would like to have a clock position announcement of ADU threat.

ATM Task 1162 – Actions on Contact

High Workload When Performing Actions on Contact (four comments)

- Actions on contact with evasive maneuvers requires all attention to flying aircraft related systems.
- Actions on contact is stressful because of trying to see enemy quickly as you are turning away from it and tell front seater where to go.

- Breaking contact with every vehicle requires almost all the attention of the pilot on the controls.
- When breaking contact with enemy, almost all attention is directed to flying the aircraft NOE to a covered position.

Other Problems (four comments)

- Trying to evade from enemy, the simulator does not represent distinctions between high and low ground soon enough.
- It is very difficult to judge aircraft altitude.
- HMD turns blank when engaged by the threat which results in no visual outside.
- Would like a clock heading from ASE threat.

ATM Task 1230 – Inadvertent IMC Procedures

- All attention is for TSD operations and flight planning management.
- When you suddenly go IMC, the pilot has to move hand from controls to hit HAT on TSD.
- Flying instruments and using HAT on TSD requires all attention.

ATM Task 1245 – Unusual Attitude Recovery

- Trying to evade from enemy, the simulator does not represent distinctions between high and low ground soon enough.

ATM 1300 – Emergency Procedures

- WCA could not be acknowledged from front seat. It stayed up on the TSD.

ATM Task 1410 – TSD Operations

- When busy scanning in back seat, have little time to look at TSD.
- Very difficult to locate specific NAIs and POI when far away.
- When many targets populate TSD, it becomes very difficult to keep them separated. Can't push all the required buttons fast enough.
- Many buttons to press when dispositioning targets. Remembering to press "TSD Home" every time is aggravating. Causes loss of SA.
- TSD was extremely busy. Tried to use overview, but didn't have time to go through who labeling process.
- When near enemy main body, TAS becomes very saturated but it is better than not having a TSD.
- AMC over-tasked with tasks.
- If you inadvertently "no-target" your wingman, it is very difficult to maintain battlefield SA.

ATM Task 1422 – Firing Techniques

- When operating a digital remote mission, pressing the 'show on map' should slew TAS on to the target automatically.
- MOPP gloves make engagements difficult.

ATM Task 1442 – HIDSS Operations

- Evasive maneuvers at 100 knots at 20 AGL.
- The TAS BUPS didn't function on this flight (simulator problem).
- Heading tape disorienting.
- Backseat HIDSS was not working.

ATM Task 1448 – EOTADS Sensor Operations

EOTADS is Difficult to Slew While Aircraft is Moving (seven comments)

- EOTADS is very difficult to manually slew while moving. It is too jumpy, but I was forced to do them because the scan "fingers" only extended less than 500 meters most of the time.
- Sensor ops difficult when moving. Difficult to look at area of interest.
- EO TADS slew rate is difficult to control during movement. I think a wide FOV would be useful as well when maneuvering thru mountains.
- During maneuver flight, hard to impossible to track targets of interest.
- Manual slewing of TAS difficult while flying.
- Manually slewing EOTADS while flying is very difficult. Might be helpful to be able to change slew hook sensitivity so at times you can slew faster and at other times you can slew slower.
- Hard to fly and use the EOTADS.

<u>Manual Slewing of Sensors is Workload Intensive</u> (three comments)

- Backseat operation of EOTADS in manual mode search requires all my attention.
- Manual searching requires almost all attention of back seater.
- Manual EOTADS slewing is difficult when in mountainous terrain.

Other Problems With EOTADS (12 comments)

- Utilizing TAS while flying near terrain is very difficult. I almost crashed twice because I was trying to look at target picked up by the radar.
- No situational awareness when sending digital messages due primarily to CIK being cumbersome to operate.
- During EOTADS operation, my attention was more devoted to EOTADS operations and less toward the mission. I had to continuously employ my sensors and keep up with the mission.
- Hard to do any other tasks while trying to scan route or area.
- Sometimes you inadvertently turn off continuous scan or radar on EOTADS. (Pilot unsure of how he inadvertently turned off continuous scan and radar on EOTADS).
- When checking multiple messages, you can not manually scan.
- When checking messages, you cannot scan.
- Difficult to use rapidly when trying to ATS targets. ATS doesn't always work well.
- AMC over tasked with tasks.
- Too hard to operate TAS and fly.
- EOTADS was not working properly. It slowed efficiency.
- EOTADS is very difficult to use at close distances. FOV is too narrow in 'Medium'.

ATM Task 1449 – Digital Communications

Cockpit Integrated Keyboard (CIK) Was Difficult to Use (24 comments)

- Keyboard is slow for entering data.
- Takes too long for free text messaging.
- Take too long to create and send digital messages. Takes away from other tasks.
- Sending free text is still cumbersome while looking down hunting for keys. A QWERTY key board would allow to type and at least review CHIPs at the same time.
- CIK inputs - need QWERTY keyboard.
- Free text is too difficult with long messages. I prefer secure voice.
- Tough to send free text messages because they require being inside cockpit for too long.
- Messages take too long. Takes away from mission.
- Data management with this keyboard takes to long.
- When creating or sending reports, you have no situation awareness (SA) with the battle.
- Non-QWERTY keyboard.
- Keyboard should be QWERTY.
- Keyboard is too time-consuming for typing messages.
- CIK was hard to manipulate with NBC gloves along with the HOG and SAC switches.
- When managing or creating text messages or tactical reports, it takes away from primary tasks.
- When engaging multiple targets, you may not have enough time to send BDA or Spot Reports. Also, when sending text messages, it takes too long (due to the CIK).
- Trying to send dig coms takes away from scanning which is the task at hand.
- Took too much time to send free text messages while trying to fly.
- CIK is difficult and time-consuming to type (due to non-QWERTY layout).
- Need a QWERTY layout for CIK.
- Non-QWERTY keyboard.
- Almost hit ground once when looking down to input a free text message in the CIK.
- CIK inputs – non-QWERTY layout.
- CIK is too cumbersome.

Other Problems (five comments)

- When digital traffic gets busy, back seater has little situational awareness as to what is happening.
- When getting free text messages, it takes too long to create a route or locate points.
- Front seater checking multiple messages and sending while in flight for AMC.
- The BDA reports was not working right because it would often not allow me to send the message after giving a target a status.
- AMC over tasked with tasks.

ATM Task 1451 – FCR Operations

- Sometimes you inadvertently turn off continuous scan or radar on EOTADS. (Pilot unsure of how he inadvertently turned off continuous scan and radar on EOTADS).
- FCR – Continuous scan in Map mode required multiple attempts before radar would slew in desired direction.

- Operating FCR while flying overloads the flying pilot.
- Sometimes you get too busy and have to revert to using 340 degrees GTM scan FOV.
- Continuous scan modes disengage when TAS is passed from crew member.

ATM Task 1454 – Data Entry Procedures

Cockpit Integrated Keyboard (CIK) Was Difficult to Use (78 comments)

- The CIK is just a cumbersome and slow method to enter data. A QWERTY style keyboard would be much faster and efficient.
- CIK buttons are too small and layout too difficult to use efficiently. Need a QWERTY layout.
- Keyboard cumbersome and awkward.
- Free text is too difficult with long messages. I prefer secure voice.
- Cannot scan when checking messages.
- Took too much time to send free text messages while trying to fly.
- Tough to send free text messages because they require being inside cockpit for too long.
- Keyboard is slow for entering data.
- CIK is difficult and time-consuming to type (due to non-QWERTY layout).
- Takes too long for free text messaging.
- When digital traffic gets busy, back seater has little situational awareness as to what is happening.
- Still slow to send free text messages via CIK. Also lost SA while looking down.
- Too difficult and cumbersome to input data via the CIK due to non-QWERTY layout and lack of TAB key.
- Free text takes too long due to layout of keyboard (non-QWERTY), lack of TAB key, and having to apply a lot of force to depress CIK keys.
- CIK inputs – non-QWERTY layout.
- Hard to enter free text message and maintain SA while inputting.
- The CIK isn't user-friendly, difficult to efficiently input data.
- Take too long to create and send digital messages. Takes away from other tasks.
- Free text entry is difficult and time-consuming.
- Very inefficient to input data via CIK.
- CIK is too cumbersome.
- Sending free text is still cumbersome while looking down hunting for keys. A QWERTY key board would allow to type and at least review CHIPs at the same time.
- CIK inputs non QWERTY.
- CIK requires full attention while typing.
- CIK too inefficient means of data entry.
- Messages take too long. Takes away from mission.
- CIK isn't efficient with data entry.
- Data management with this keyboard takes too long.
- Entering free text message takes total devotion of attention.
- CIK entries QWERTY.
- Very hard to use CIK because it forces you to look down the whole time to type in a message.
- CIK entries QWERTY to enter.

- Data Entry – I used the text bar for most of the messages I sent today since I was flying. I would like to make all selections with the cursor and not have to switch between the cursor and pushing buttons.
- CIK very inefficient means of data entry.
- CIK is inefficient.
- CIK is too cumbersome.
- CIK inputs were QWERTY.
- When getting free text messages, it takes too long to create a route or locate points.
- It takes way too long to input data via CIK.
- CIK entries – QWERTY keyboard.
- CIK entries are time consuming and do not allow another task to be checked.
- Only able to type when using CIK.
- CIK is slow and uses all attention.
- CIK entries are non-QWERTY.
- Typing takes too long and requires all aviators' attention.
- No QWERTY keyboard.
- When creating or sending reports, you have no situation awareness (SA) with the battle.
- The CIK is very cumbersome and difficult to efficiently enter data.
- Non-QWERTY keyboard.
- CIK entries due to non-QWERTY keypad.
- When operating a digital remote mission, pressing the 'show on map' should slew TAS on to the target automatically.
- Keyboard too cumbersome (and hard to find letter and #'s).
- CIK too slow to use effectively.
- CIK "ABC" format is very cumbersome.
- CIK is cumbersome.
- CIK is slow and cumbersome. Cannot do anything else when typing.
- CIK is very cumbersome and makes it difficult to input infor.
- CIK is cumbersome which makes it difficult to input data.
- Keyboard should be QWERTY.
- CIK slow and cumbersome. Cannot do anything else when typing.
- No situational awareness when sending digital messages due primarily to CIK being cumbersome to operate.
- CIK is too cumbersome for data input.
- CIK is very cumbersome.
- Keyboard is not user-friendly.
- Keyboard is too time-consuming for typing messages.
- CIK is very bad.
- Keyboard has inconsistent operations.
- CIK is difficult to use.
- CIK is slow and cumbersome requiring us to look down throughout the inputting of text.
- CIK is a no-go.
- Inputting a message into the CIK was slow and cumbersome. Required my full attention.
- Non-user friendly keyboard.
- Takes too long to input text into CIK.
- CIK was hard to manipulate with NBC gloves along with the HOG and SAC switches.
- When managing or creating text messages or tactical reports, it takes away from primary tasks.

- Non-user friendly keyboard.
- CIK sucks!
- When engaging multiple targets, you may not have enough time to send BDA or Spot Reports. Also, when sending text messages, it takes too long (due to the CIK).
- CIK is slow and cumbersome requiring the pilot to look down and only focus on one thing.

ATM Task 1455 – Data Management Procedures

Cockpit Integrated Keyboard (CIK) Was Difficult to Use (seven comments)

- Keyboard cumbersome and awkward.
- When engaging multiple targets, you may not have enough time to send BDA or Spot Reports. Also, when sending text messages, it takes too long (due to the CIK).
- Messages take too long. Takes away from mission.
- Data management with this keyboard takes too long.
- No situational awareness when sending digital messages due primarily to CIK being cumbersome to operate.
- CIK is non-QWERTY.
- CIK is very inefficient.

Other Problems (five comments)

- When digital traffic gets busy, back seater has little situational awareness as to what is happening.
- When getting free text messages, it takes too long to create a route or locate points.
- When creating or sending reports, you have no SA with the battle.
- When managing or creating text messages or tactical reports, it takes away from primary tasks.
- Back seater getting me to check messages and send data while I'm flying.

ATM Task 1458 – Engage Target With PTWS (Hellfire)

- Could not get constraint symbology in backseat.
- No symbology in aft HMD for Hellfire engagement.

ATM Task 1464 – Engage Target With AWS (20 mm)

<u>Simulator Problems</u> (six comments)

- No target effect.
- No target effect for every engagement.
- No target effect on dismounted troops (couldn't tell if dismounts had been killed by 20 mm).
- For some reason, target would not ATS, so it was too tough to shoot.
- No target effect. Gun had no effect on target.
- No target effect with 20mm gun.

Other Problem (one comment)

- MOPP gloves make engagements difficult.

ATM Task 2157 – Multi-Ship Operations

Problems Attributable to "No-Targeting" Other Comanche Aircraft (five comments)

- Ship very difficult today because I had no targeted my wingman and we lost EPLRs data from him.
- Sistership no targeted our icon on his TSD and we had to maintain separation and guide him to our location for link up.
- Wingman's icon disappeared off our TSD. Took time away from flying trying to keep a visual on where our wingman was.
- No target of sistership made these tasks harder.
- If you inadvertently "no-target" your wingman, it is very difficult to maintain battlefield SA.

Other Problems (two comments)

- Radios in CPC and EDS are not working well. Volume is too low from CPC to EDS.
- Simulator was not working properly and lost SA of other aircraft.

ATM Task 2476 – Security Mission

- We let a vehicle sneak up on us underneath our sensor and did not find him until he was engaging us.

ATM Task 2500 – Aerial Observation

- Due to air route in mountainous terrain. Not a lot of observation points.
- Difficult to maneuver through the terrain and get good sensor coverage on both route and surrounding terrain.
- Non radar aircraft had to maneuver more to scan terrain (than the radar aircraft).
- Admin – was not allowed to use black hot on NVS system.
- No NVD system for the back seat.

ATM Task 2502 – Area Reconnaissance

- Situation difficult (for this specific mission) to accomplish with no support (e.g., no wingman or CAS).

ATM Task 2511 – Route Reconnaissance

- Due to air route in mountainous terrain. Not a lot of observation points.
- Difficult to maneuver through the terrain and get good sensor coverage on both route and surrounding terrain.

ATM Task 2514 – Zone Reconnaissance

- Zone was too big to clear sufficiently.

ATM Task 2538 – Digital Artillery Mission

- Digital artillery would be useful if it said what target #'s a specific mission was for in the TIAP.
- The missions displayed on TIAP should display what target Arty is engaging.

ATM Task 2539 – Digital Remote SAL Missile Mission

- When operating a digital remote mission, pressing the 'show on map' should slew TAS on to the target automatically.
- If you inadvertently "no-target" your wingman, it is very difficult to maintain battlefield SA.
- If wingman loses EPLRS, you can't quickly tell if you are in constraints for a remote shot.
- Sister ship icon was no targeted. Could not tell if they were within limits for shot.

ATM Task 2548 – Transmit Tactical Reports

<u>Takes Too Long to Create and Send a Digital Message</u> (six comments)

- Take too long to create and send digital messages. Takes away from other tasks.
- When engaging multiple targets, you may not have enough time to send BDA or Spot Reports. Also, when sending text messages, it takes too long (due to the CIK).
- Messages take too long. Takes away from mission.
- No situational awareness when sending digital messages due primarily to CIK being cumbersome to operate.
- When creating or sending reports, you have no situation awareness (SA) with the battle.
- When managing or creating text messages or tactical reports, it takes away from primary tasks.

Other Problems (seven comments)

- Cannot scan when checking messages.
- When sending a BDA from task bar, the status doesn't send with the report.
- Back seater getting me to check messages and send data while I'm flying.
- AMC over tasked with tasks.
- Transmitting tactical reports takes away from different tasks in the cockpit.
- When getting free text messages, it takes too long to create a route or locate points.
- When digital traffic gets busy, back seater has little situational awareness as to what is happening.

ATM Task 2805a – Identify Major U.S. and Allied Equipment

- No intel about all vehicles in column (was provided to crews).

ATM Task 2805b – Identify Major Threat Equipment

- Track vehicles at distances from 5k and up when they are viewed head on, they look similar.
- Situational awareness degraded when friendly and enemy icons were close together and actions from the crew in the aircraft requires defensive posture (shot 20 mm at friendly vehicle when we flew over a ridge and were surprised).

ATM Task 2823 – Operate Aircraft Survivability Equipment

- Would like to have a clock position announcement of ADU threat.

ATM Task 2837 – Operate Night Vision Pilotage System

- Video graphics are poor.
- The simulation graphics are poor and hinders ability to properly fly the simulator.

List any flight and-or mission tasks that you had to ask your crewmember to accomplish because your workload was too high.

<u>Back Seat Responses</u>

<u>Had Front Seat Crew Member Perform Communication Tasks</u> (63 comments)

- Often send digital reports.
- Had the front seat check messages to send digital messages while I scanned for targets because it seemed more important.
- I asked for front seater to read reports when they came in.
- Tasked my front seater to operate EOTADS and send digital messages.
- Had front seater check messages and make radio calls.
- Send free text messages.
- Send spot and BDA messages.
- Sending BDA, spot reports.
- Send spot (text/SITREP/BDA/ARTY CFF).
- Comms with other Comanche aircraft (Demon 35).
- Check messages.
- Send SPOT, BDA messages.
- Passed off spot reports, BDAs, Free text, call for fire.
- Had the front seater create free text messages and check messages.
- Had the front seater enter data and transmit voice messages.
- Had the front seater send SPOT reports and BDA, talk to the wingman.
- Had front seater send BDA reports and call for fire digitally.
- Had front seater check messages, handle radio communications, ARTY and BDA messages.
- Had front seater send BDA, SPOT reports and SITREPs.
- Had front seater answer messages.
- Had front seater get many messages, send Spot reports, sent free text messages, and make radio calls.
- Had front seater send Spot reports and do BDAs.
- Had front seater check messages, send Spot, BDA and SitRep reports, talk to wingman.

- Front seater checked messages, made radio calls, sent Spot reports and BDA.
- Had front seater check messages and send messages.
- Had the front seater do BDA, Spot report and Arty tasks.
- Had front seater check reports and send messages.
- Had front seater answer messages, call for Arty, and send Spot reports and BDAs.
- Had front seater check messages, send messages, send Spot reports, send BDAs, and send fire-for-effect (FFE) mission.
- Asked front seat to view messages while I scanned an intersection coming out of city.
- Asked front seater to send spot and BDA reports.
- Asked him to send "Free Text" messages for route status.
- Had front seater checking messages and sending BDA reports.
- Had the front seater answer and read messages.
- Had the front seater send SPOT and BDA reports.
- Had the front seater send digital artillery.
- Asked my front seater to check free text and other reports, send BDAs and SPOT reports.
- Had front seater send Spot/BDA reports.
- Had front seater check inbox (for messages).
- Had the front seater check text messages.
- Had the front seater check messages, send SPOT reports/BDA.
- Had front seater send SPOT/SITREP/BDA reports.
- Check text messages, spot reports, etc.
- Had front do several BDA's and spot reports near end of mission.
- Send free text messages.
- Send BDA & SPOT reports.
- Passed off checking messages.
- Send spot reports and BDA reports.
- Check messages, sent BDAs and SPOT reports.
- Xmit, Spot, Free text.
- Had the front seater send spot reports and read messages.
- Had the front seater check messages, send Spot reports, call for fire.
- Had front seater check SPOT/Text/SITREP messages.
- Had front seater check messages.
- Had front seater transmit SPOT and SITREP messages.
- Had front seater answer digital messages while I entered text using the CIK.
- Had front seater check messages.
- Had the front seater check some messages, send SPOT reports, BDAs, and artillery missions, and make radio calls.
- Had front seater check messages.
- Had front seater answer digital messages.
- Had front seater check messages.
- Had front seater check messages.
- Had front seater send Spot reports, BDAs, and do radio comms.

Had Front Seat Pilot Operate Sensors (28 comments)

- Tasked my front seater to operate EOTADS.
- Had the front seater take the TAS and do scans.
- Front Seater took TAS while I was text messaging.

- Passed off EOTADS, Radar to front seater.
- Had the front seater use TAS.
- Had front seater do EO scans.
- Had front seater check Chips on TAS.
- Had front seater operate TAS.
- Used TAS while I am sending free text.
- Had the front seater take TAS when back seater was creating text messages.
- One time, I asked the front seat to operate sensors while I set-up free text message.
- Had front seater use the radar.
- Had front seater operate the TAS.
- Had front seater look for enemy.
- Had the front seater operate TAS.
- Had the front seater use the TAS.
- Had the front seater use TAS while I created a route and we were at a hover.
- Had front seater operate TAS.
- Use TAS while inside for extended periods.
- Passed off working EOTADS.
- Use TAS while I was inside.
- TAS operations.
- Had the front seater operate the radar and operate the TAS.
- Had front seater take TAS while entered text using the CIK.
- Had front seater operate radar.
- Had front seater operate TAS.
- Had front seater operate radar.
- Had front seater operate radar.

Had Front Seat Pilot Perform Target Engagement Tasks (four comments)

- Had the front seater shoot with HIDSS (20mm) when the TAS was not effective.
- Had the front seater engage target with HIDSS.
- Had front seater submerge targets after engagements.
- Had the front seater engage target with gun via HIDSS.

<u>Front Seat Responses</u>

Had Back Seat Pilot Perform Navigation Tasks (eight comments)

- Help with terrain flight navigation.
- Bring up a route to fly that I already created.
- Needed back seat to assist in air space surveillance and terrain navigate with BUPS.
- Asked back seater for 'direct to' and for help to identify location of NAI and OP's.
- Asked back seater to find NAIs because I couldn't take hands off controls to look around on TSD. Asked to help locate Ops because TSD was too cluttered to see them clearly.
- I had my back seater give me 'direct to".
- Had my back seater build routes on the "fly".
- Had him locate NAI's and Ops because I couldn't search the TSD while flying.

Other Tasks (six comments)

- Once, could not answer a message because I was too busy.
- Had to have back seater perform fuel check while I was flying.
- No work I passed off, but sometimes I could not do tasks that were delegated to me by co-pilot because I was too busy flying.
- Checked messages.
- Time to ensure the right button was selected. Could not know if correct button was selected by feel.
- Had to tell pilot in back seat that I could not assist with reading some messages when I was conducting terrain flight.

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Appendix I. Summary of Pilot Ratings and Comments About Usability of the Crew Station Controls, Displays, and Subsystem Interface

For each functional component, indicate whether you experienced a problem using the component in a quick and efficient manner. Check "Yes" if you experienced one or more problems. Check "No" if you did not experience any problems. Check "Not Used" if you did not use the component.			
TSD Functional Components			
	Yes	No	Not Used
TSD Overlay	2%	80%	18%
TSD View	0%	91%	9%
TSD Tools	4%	89%	7%
TSD Windows	9%	56%	35%
TSD Config	0%	98%	2%
TSD Toolbar	31%	65%	4%
TSD Home	0%	100%	0%
NAV Plan	9%	91%	0%
NAV Curr	4%	96%	0%
HMD Mode	0%	100%	0%
IMAG Config	0%	100%	0%
SMD Functional Components			
	Yes	No	Not Used
SMD COMM FS	16%	84%	0%
SMD COMM Reports	4%	96%	0%
SMD COMM CONFIG	0%	100%	0%
SMD COMM TUNE	7%	91%	2%
SMD COMM PSET	0%	100%	0%
XPNDR	0%	98%	2%
FLT INST	0%	98%	2%
ENG INST	0%	98%	2%
TAS	13%	85%	2%
WCA	13%	49%	38%

Pilot Comments:

Problems with TSD Toolbar (14 comments)

- TSD Tool bar – Cursor pressure required to slew is sometimes sufficient to depress the button and hook items unintentionally.
- TSD Toolbar – Sometimes BDA Report will send empty report to recipients of BDA report.
- TSD Toolbar – When scrolling at bottom corners for change of menu or send option on right, the cursor should be less sensitive when moving the map in those directions.

- TSD Toolbar – My right slew hook would not select anything on the TSD, so I could not use the Toolbar. Also, when sending BDA from the Toolbar, the status when selected sometimes takes the 'Send' capability away from the Toolbar.
- TSD Toolbar – Sometimes, I cannot get the BDA reports to send when using the message bar. I had to send the reports via the COMM FS BDA page. This problem did not degrade the mission much, but it slowed me down significantly.
- TSD Toolbar – When trying to send BDA via toolbar, the status doesn't show up to the recipient of the report.
- TSD Toolbar – In some instances, when the toolbar was in use at the same time the CIK was enabled, user was unable to transfer information on CIK to the SMD by pressing the enter key on CIK.
- TSD Toolbar – When sending a BDA report after selecting the status, the send button did not become active.
- TSD Toolbar – Sending BDA when you pick status of target sometimes it deselects the send button.
- TSD Toolbar – When selecting a target for BDA, you have to pick the status from a pick list and then from the Toolbar, you have to select 'Send'. Sometimes, after selecting a target and status, the 'Send' button does not illuminate.
- TSD Toolbar – When doing a BDA from the toolbar, it defaults to "Destroyed" and sometimes it doesn't. Also, the status doesn't show up on the receiver's end. This caused the receiver to request the status again.
- TSD Toolbar – Sometimes, the status of the target (destroy, etc.) doesn't send with the BDA report.
- When doing BDA from toolbar, the status is not retained when the BDA is sent. This reduces the efficiency of the system.
- BDAs sent via toolbar sometimes don't send the status.

<u>Problems with WCA</u> (seven comments)

- WCA – This information needs to be more detailed and organized. We had problems with our engine, but the WCA only said left engine out.
- WCA – Audio needs to be higher pitch.
- WCA – Could not acknowledge WCA's off the TSD by accessing WCA button on HOG or WCA hard bezel.
- WCA – When trying to clear faults the WCA button did not work on the collective.
- WCA – Couldn't acknowledge a message in the CPC front seat. The WCA button on the HOG and
- WCA hard bezel wouldn't action advisory away on the TSD.
- WCA – Sometimes, when encountering an emergency message (i.e., ENG 1 Out) the message doesn't display on the WCA page right away. It took a few minutes for the message to appear on the WCA page.

Problems With SMD Comm FS (six comments)

- SMD COMM FS – I would like a TSK target # duplicated in the TIAP when I call an ARTY mission. This would help keep track of what mission is for what target. This problem did not degrade the mission much, but it slowed me down significantly.
- SMD COMM FS – I think the COMM FS should add the aircraft assigned target number to the TIAP display. This makes it easier to keep multiple calls for five straight rather than just mission 1, 2, etc. as it is currently modeled.
- SMD COMM FS – Should list the target # next to any call for fire. This would allow much easier tracking of Arty missions when more than one is active.
- SMD COMM FS – Need to know what Arty mission is for what target from the TIAP display.
- SMD COMM FS – TIAP doesn't display target number.
- Comm FS – Does not give a target # for each arty mission would be easier to keep track of multiple missions.

Problems With TAS (five comments)

- TAS - When the aircraft is on the move, it is almost impossible to slew EOTADS manually due to its position on the aircraft (nose) and its sensitivity.
- TAS – I used the "ENG" button on the TIAP, but it required two button pushes to make it work. This made finding 2S6's slower and more difficult.
- TAS – If I am reviewing CHIPs after an automated scan and if I select no target then the icon should disappear completely rather than become just a dot.
- TAS – If a target is no-targeted accidentally, there is no way to reacquire the target. (i.e., ATS, IAT). There should be a way to do a locate function by utilizing laser energy and ATD-C.
- TAS – Sometimes the 'ENG' button on the TIAP did not function. Sometimes, the 'FIND' switch does not function or it slews the TAS to the wrong target.

Problems With TSD Window (four comments)

- TSD Window – When selecting a group details button, it does not open a TSD Window. Minimal degradation. Recommend fixing to allow easier target selection within a group.
- TSD Windows – Locks-up simulation.
- TSD Window – Selection of windows defaults to a 1 KM picture. Too small of an area/loose time and situational awareness.
- TSD windows if you scale all the way down, you will lock the simulator up.

Problems With SMD Comm Reports (four comments)

- SMD COMM Reports – Digital reports should have some highlight system of all-important information (i.e. from who, what grid, etc.).
- SMD Comm RPTS – The free text message is slow and cumbersome with the CIK.
- CRR FFE displayed on TIAP doesn't show which target is being serviced.
- The TAS and Radar switches should be on different panels.

Problems With NAV Plan (three comments)

- NAV Plan – Tried to modify the current route and it didn't work properly. Forced me to make a new route. Recommend allowing re-editing of current route.
- NAV Plan – Cannot append a way point to the route if you stop and do something else in the middle of creating the route.
- NAV Plan – Current means of entering flight plan information is too cumbersome and time consuming to receive in flight.

Problems With NAV CURR (three comments)

- NAV CURR – Direct to is awkward in use because it will not automatically draw line to selected point, target, or waypoint.
- Can't insert pre-saved POI's or points into a flight plan. Would like to be able to insert points from a pick-list.
- NAV CURR – Should always default to FPLAN list when hard bezel selected and not require a selection off of the TMI. This is confusing and made me think that the simulator was broken when it didn't default.

Problems With SMD Comm Tune (three comments)

- SMD COMM TUNE – Securing the UHF and VHF radios in the CPC (is a problem). After selecting KY and then pressing secure soft bezel, you have to off-tune the frequencies and come back for it to actually go green on the RMPD. Securing radios, you have to select KY variable (using the CIK is very difficult) before securing the radio. These add great time to the tasks at hand.
- SMD COMM TUNE – Comm tune page had two different problems. First, would not let me (back seat) make radio 4 secure. Front seat was able to go secure. Second, on different day, I made radio 4 secure, but it made radio 3 secure instead. Neither of these problems affected the mission, but they slowed start-up.
- SMD COMM TUNE – When trying to change a radio from "p" plain to "c" cypher, it changed the wrong radio that wasn't even selected.

Problems With TSD Tools (two comments)

- TSD Tools – Forget to turn off point-to-point bar. Minimal degradation. Recommend a max time for bar to exist of 30 seconds.
- TSD Tools – The locate function is not intuitive. Most always, you use the locate function in conjunction with the DIRECT-TO function. The TSD map will reset to the home position after you initiate a locate which makes it difficult to apply a DIRECT TO to that point. Usually you forget where exactly that POI was.

Problem With TSD Config (one comment)

- TSD CONFIG – BDAs sent from task bar sometime will send without the status of the target (i.e., destroyed).

Problems With TSD Overlay (one comment)

- TSD Overlay – The update button was confusing and I had to relearn how to use it with the mockpit when I couldn't get it to work immediately in the CPC. This problem did not degrade the mission much, but it slowed me down significantly.

Indicate whether you experienced a problem using the EOTADS sensor functionality in a quick and effective manner.			
	Yes	No	Not Used
FLIR Operations	9%	89%	2%
DTV Operations	0%	13%	87%
Tracking Operation	42%	53%	4%

Tracking Operations (22 comments)

- Difficult to manually track while aircraft is moving. Degrades target tracking significantly. Recommend decreasing sensitivity of left slew hook while aircraft is in motion.
- When the aircraft is on the move, it is almost impossible to slew EOTADS manually due to its position on the aircraft (nose) and its sensitivity.
- In flight greater than 60 knots and in turns greater than 5-10 degrees, the TAS manual manipulation is difficult to impossible.
- Tracking with FLIR while moving is extremely difficult. This made performing recon difficult if the aircraft was not stopped.
- Tracking operation is very difficult to perform manually while moving. The slew hook seems too sensitive because when flying, I over-control the TAS and it is difficult to center it over a suspected target.
- Very difficult to do a manual scan with TAS if the aircraft is moving.
- When performing manual scans with the EOTADS, the sensor movement is very erratic and difficult to control while the aircraft is moving. It is better in Medium field of view than narrow field of view but I think that a wide field of view may be even better at allowing the front seater to look for targets while moving. Otherwise the TTPs should recommend more automated scans while moving.
- Manual tracking of the TADS is very tough while the aircraft is moving. Still possible just not as accurate.
- Tracking is difficult while flying or maneuvering in an OP. It would be useful to be able to change the slew rate for the EOTADS so when moving through various terrain, you could have a better picture. And when tracking a target, you could make fine adjustments.
- Sensor doesn't slew smoothly. It is difficult to scan terrain smoothly.
- Need to be able to adjust sensitivity of left slew hook so that you can move EOTADS faster to slower as necessary.
- Accidentally, no TGT an object then trying to manually track is difficult.
- No problem with Tracking operation, but no TGT function can be inadvertently accomplished. One fix for this is if you ATS a target this is saying to the system that you want this target back.
- Target was inadvertently no-targeted then there was no way to get the target again. I had to put a POI on the target, re-label it but TAS still doesn't trace it.
- If you submerge an item twice, you can't bring it back.

- If a target is 'no targeted', there is no way to recall it.
- No target function – There should be a way to recall an object if you inadvertently 'no target' it.
- You are unable to ATS a target that has been 'no targeted'.
- ATS does not always work properly. Sometimes it does not function.
- ATS and IAT would not always lock and classify a target. This causes a problem when engaging with Hellfire due to no symbology.
- ATS does not always work well. Sometimes the vehicle will not be captured by ATS unless you zoom in and position sensor accurately on the vehicle.
- ATS does not always operate. Sometimes operator must press ATS several time to 'track' target.

<u>FLIR Operations</u> (two comments)

- FLIR does not slew smoothly. It is difficult to do manual searches.
- When using the 'field-of-view' bezel button on the SMD, I inadvertently switched from FLIR to DTV. It took me a couple of minutes to find out why I lost my picture in the SMD.

List and describe any other crew station functions that you were not able to complete in a quick and efficient manner.

<u>Problems With the CIK</u> (seven comments)

- Sending free text message is too cumbersome. Requires too many button pushes to accomplish.
- Data entry through CIK.
- Creating and sending text messages.
- Sending 'free text' messages takes too long because of keypad layout and there is no down arrow key.
- I was unable to type free text messages in a quick and efficient manner because I was having to search for the letters on the non-QWERTY keyboard, and also I had to keep looking down while typing.
- Typing free text takes a long time to accomplish.
- The keyboard needs to be more like a computer keyboard for faster typing. Also there needs to be a down arrow key.

<u>Problems With Slewing</u> (five comments)

- Slew hook lost function temporarily for about 5 minutes in the back seat of the CPC.
- Slew-to-own helmet function did not work in CPC.
- Slew to-own helmet (didn't work).
- Slew-to-ownship is inoperative.
- When rapidly slewing the slew hook, the pressure required can cause the aviator to inadvertently hook on icons that are not desired. This slows TSD operations.

Problems With Creating Routes (four comments)

- Could not create a route while looking at grids sent as a free text message because I could not have both screens up at once. I had to write all the grids down first and then input them.
- Trying to create a route that was sent digitally using grids and then having to find the grids on the TSD or using the locate function takes too much time. There should be a way to show the grid on the map.
- Planning a route when sent grids via a digital message is a problem. We could not have a message and perform a 'locate' function at the same time. So, we had to write the grids down first and then enter them.
- Inputting a route when received as a free text message.

Problems With Radio Select Switch (four comments)

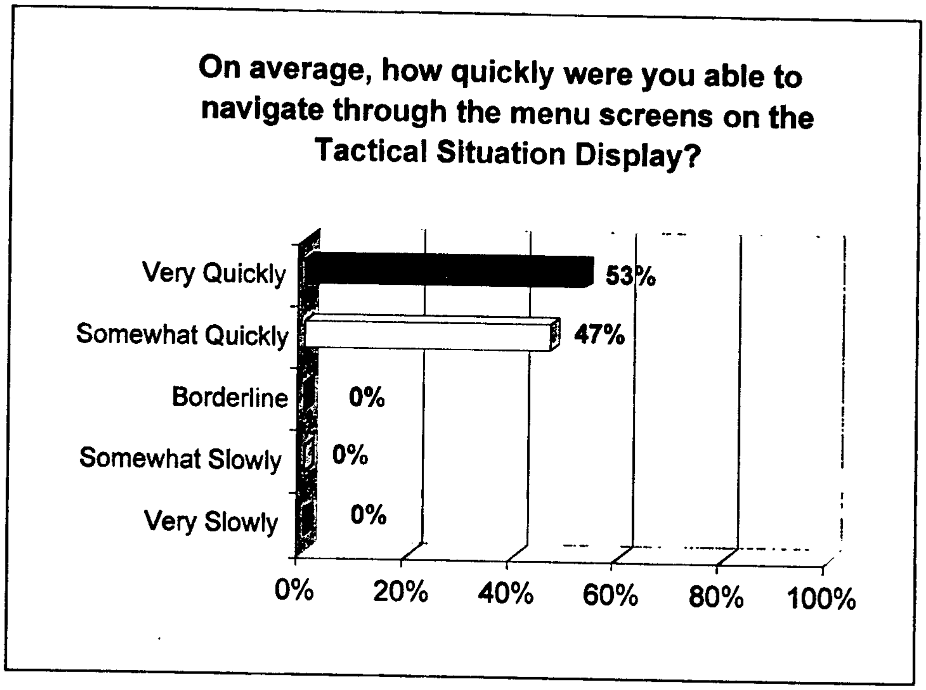
- Using the radio tune switch on the HOG is difficult.
- Tuning radios from collective is a guessing game.
- HOG radio frequency select switch is too close to the "slave-to-me" (slew-to-own-helmet) button on collective.
- I have been using the flight instruments page to change radios due to the difficulty of the radio select switch on the collective.

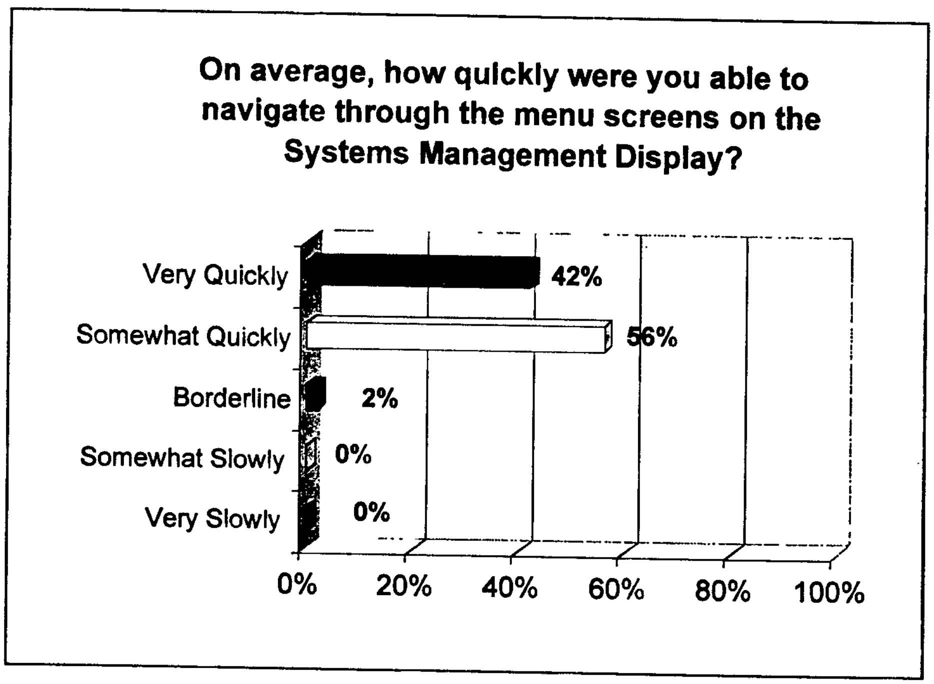
Problems With Fuel Management (two comments)

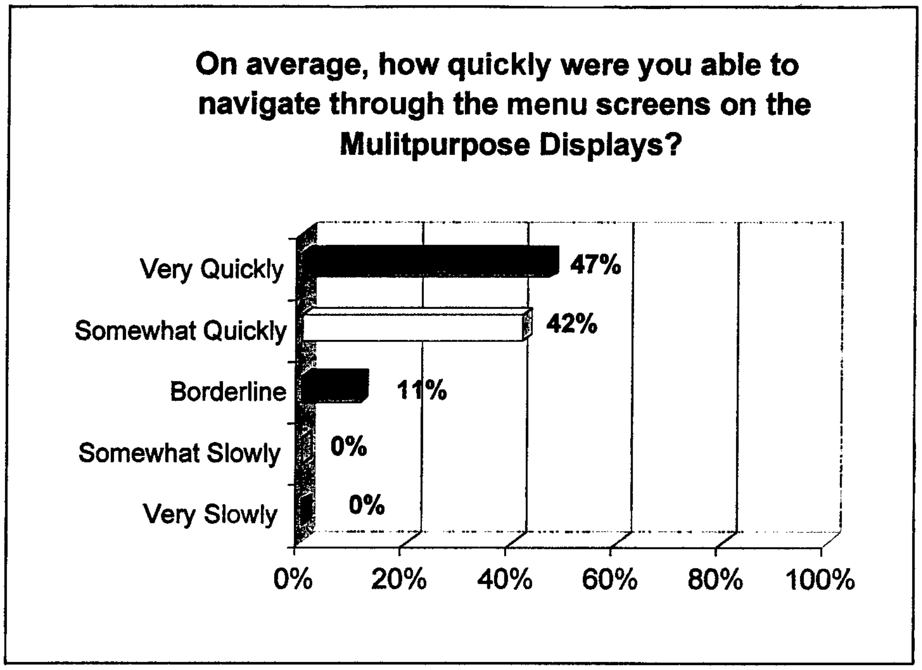
- Determining fuel management procedure IAW ATM given information on Eng page.
- Compute fuel burn-out times.

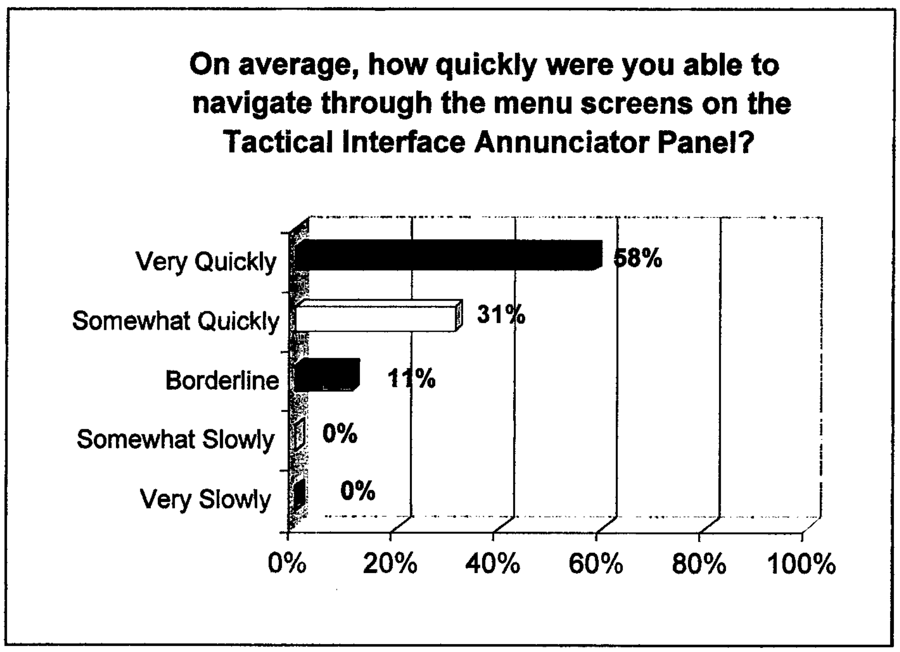
Other Comments (five comments)

- Cannot submerge group icons on TSD.
- Call artillery on a templaned position. Required to drop a point to call for fire on the templaned position.
- ATD-C target labels can't be overwritten. ATD-C incorrectly identified a BMP-21 as a tracked vehicle. If you try to overrule it, ATD-C will create another target. The TSD could show multiple targets when in fact there is only one.
- Using the "direct to" function is cumbersome.
- Tough to adjust volume with switches on the left console.


On average, how quickly were you able to navigate through the menu screens on the Tactical Situation Display?
Very Quickly
Somewhat Quickly
Borderline
Somewhat Slowly
Very Slowly
53%
47%
0%
0%
0%
0%
20%
40%
60%
80%
100%

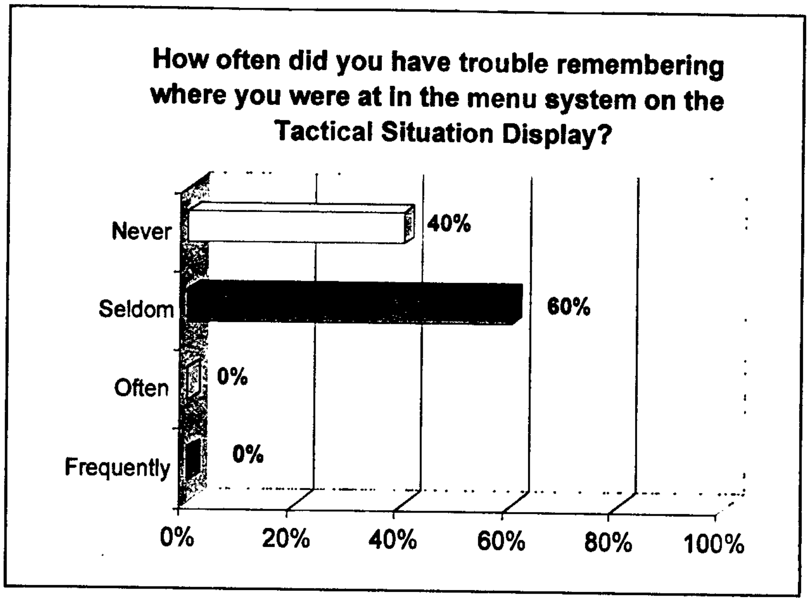

On average, how quickly were you able to navigate through the menu screens on the Systems Management Display?
Very Quickly
Somewhat Quickly
Borderline
Somewhat Slowly
Very Slowly
42%
56%
2%
0%
0%
0%
20%
40%
60%
80%
100%





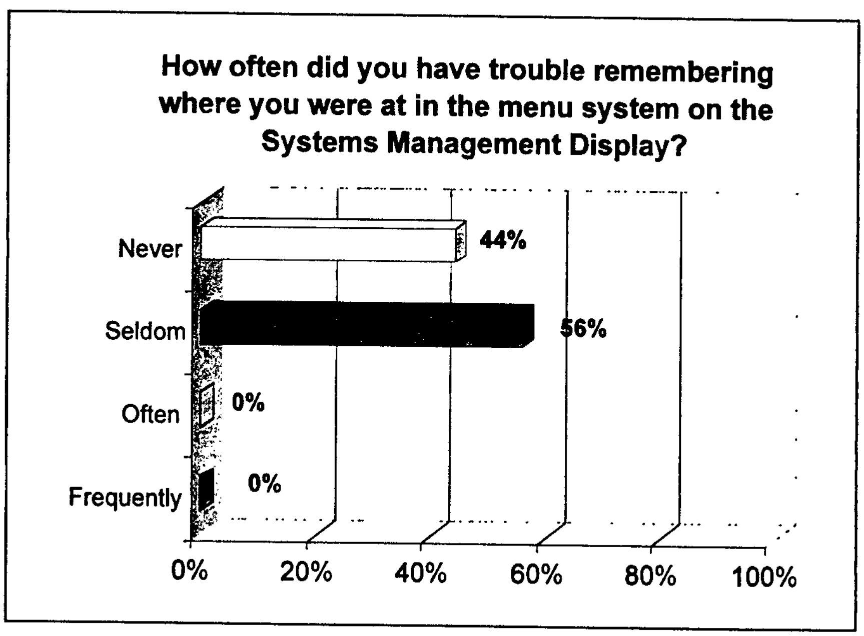
<u>Pilot Comments:</u>

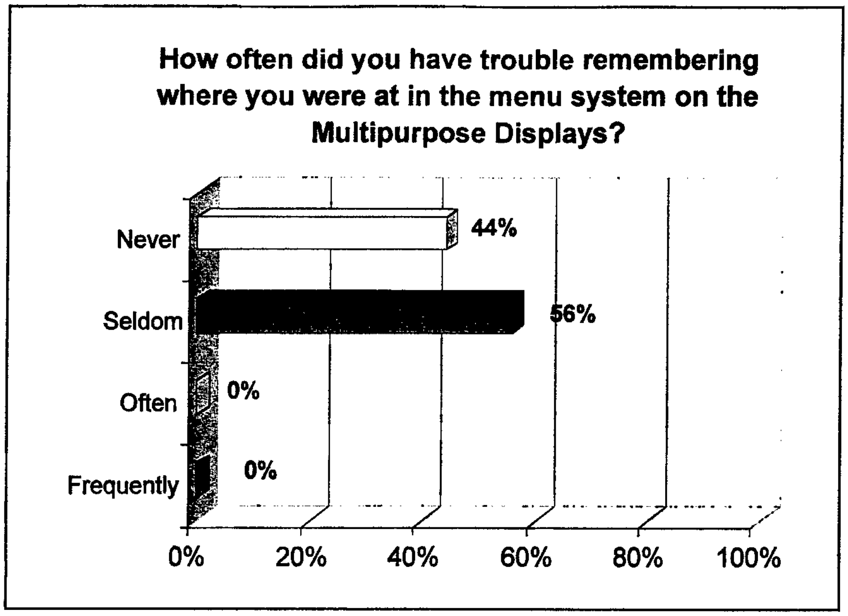
- TIAP panel display can become busy and cluttered with ASE threat, CFFs and Remotes.

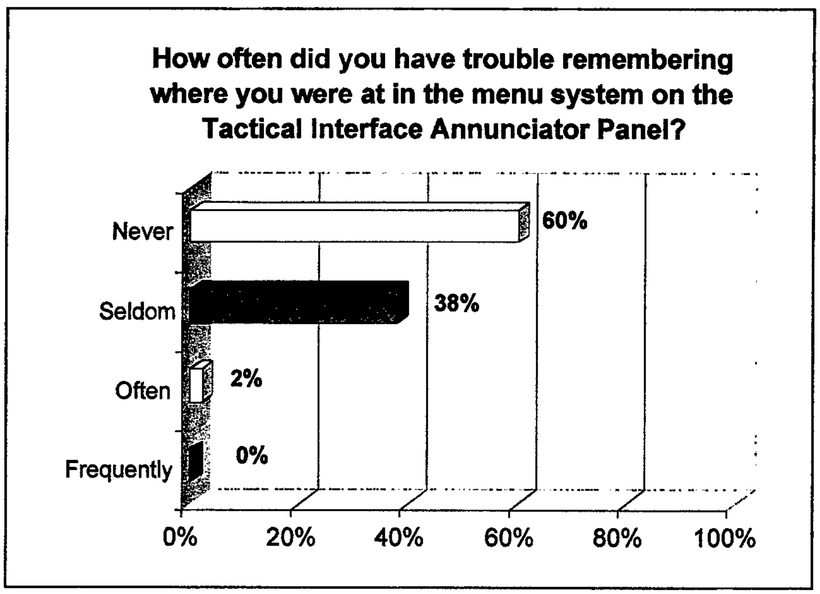


Pilot Comments:

- I do, often, find my TSD frozen because I had inadvertently moved the cursor or performed a hook and forgot to press TSD Home.

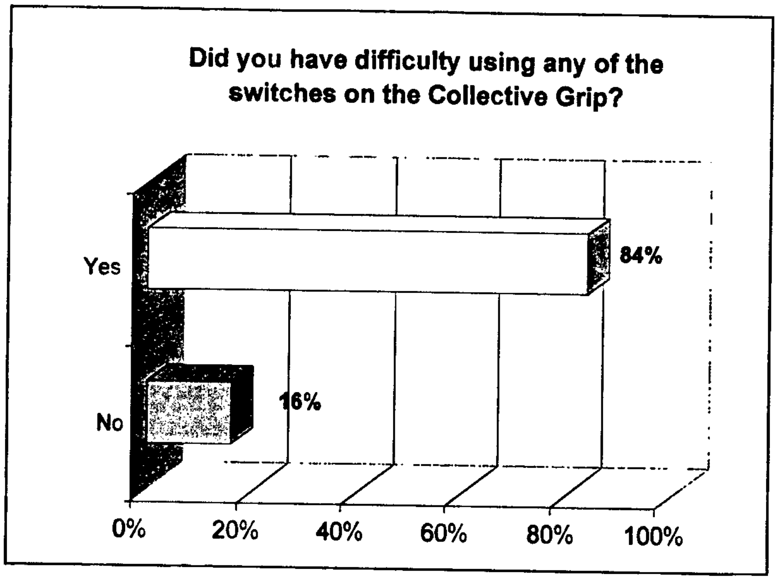






Pilot Comments:

- The TIAP doesn't display the target number associated with the call-for-fire mission.



Problems With the Radio Select Switch (25 comments)

- The radio tune switch is cumbersome and gets 'bumped' too much if you are the pilot.
- Radio select switch is at an unusual spot and is inadvertently hit and changed often.
- Radio select switch often snags on gloves and often you forget which way you press to change radios/frequencies.
- Radio frequency switch is too close to the slew-to-own button causing unwanted changing of radios and frequencies.
- In both seats, the radio switch on the collective is too easy to change presets by mistake. All of the buttons are too close.
- In both crew stations, the radio tune switch is difficult to use. Requires too little pressure to change radios.
- The radio select button was confusing at times because I inadvertently hit it and changed the frequency. I did not realize I hit the button until I went to transmit on the radio and looked on the RMPD.
- Radio tune and Select switch to close to thumb and slew to own switch.
- Inadvertently selected "NO TT". I switched a radio when I reached for the slew-to-own button.
- The radio select switch gets, inadvertently, switch many times during mission. (Both crew stations)
- Radio select switch is hit quite often on accident usually about once every two weeks.
- Inadvertently switched radios and radio frequencies. Inadvertently actioned the fun from the side-arm controller.
- Radio select switch is to close to slew to own helmet switch.
- I don't like the location of the radio select switch because I inadvertently change the radio at least once every 4 missions.
- Radio select switch needs to be stiffer as not to inadvertently actuate it.
- Radio select switch is in a place to where you can inadvertently switch radios.

- Radio select switch is too sensitive. Makes it too easy to inadvertently change radio selections.

- The radio select switch is still accidentally actioned to off-tune the radios. Even though I am aware of it, I still accidentally hit it this week.
- Radio selected inadvertently.
- The radio tune switch is difficult to use and gets bumped when using the map scale switch on the HOG. Forward/Aft and Left/Right axes for actuating radio tune switch is at an angle which makes it not intuitive.
- The radio select is inadvertently actioned and radio changed.
- The COMM switch axis of operation is different in the EDS vs. the CPC. Primarily used the switch in the back seat. The EDS COMM switch does not actuate forward/aft. It actuates off-center.
- The radio select switch is continuing. Switch is shaped the same for all axes. Doesn't distinguish between radio select and frequency select.
- The radio select switch position feels the same in each axis for radio select and frequency select
- Radio frequency switch is too close to the 'slew-to-own-helmet' switch on the collective.

Problems With the Slew-to-Own Switch (12 comments)

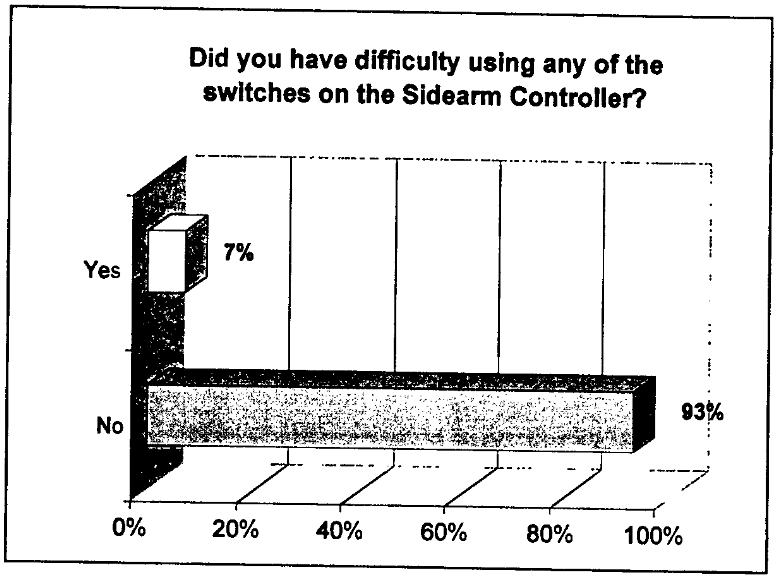
- Collective Grip – Slew-to-own helmet switch is too small and radio switch is too sensitive.
- The right slew hook switch on the collective requires too much pressure to slew rapidly.
- Sometimes confuse "slew-to-own" WCA acknowledge button and laser button.
- Slew-to-ownship is inoperative
- Using the laser and slew-to-own button is difficult with flight gloves. If the slew hook switches were centrally located in the cockpit, it would preclude the MEP operator from leaning to their left to operate sensors and displays.
- Right slew hook in both crew stations requires too much pressure to slew quickly without hooking.
- The "slew-to-own" switch feels similar to other buttons and I often depress the other buttons by mistake. The radio select switch is very unuser-friendly.
- Slew-to-own switch is too close to the radio select switch.
- The slew hook switches require enough pressure to inadvertently hook things on the TSD.
- WCA slew to own laser too small.
- When moving the right slew hook to move cursor on TSD the more pressure needed to move cursor increased chances of deselecting something on TSD.
- Slew-to-own, WCA, laser, and radio select.

Problems With No Target and Details Switches (five comments)

- No TGT button and details button are easily confused with flight gloves on. I mistakenly 'No Targeted' an object I meant to get details on.
- All seats on collective grip the details button and the No TGT switches are to close and they are the same type button.
- No target and details buttons are right next to one another and they are very easy to mistake for each other.
- NO TGT and Details switch CPC (F).
- The 'no target' and details switch are similar in size and shape (makes it easy to actuate the wrong switch). Also, the switches are too small.

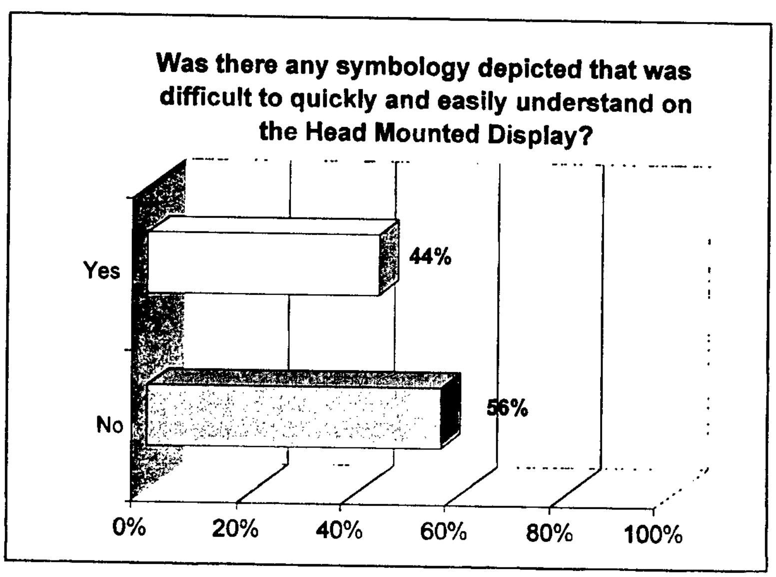
Other Comments (two comments)

- When using the map scale switch/button, your thumb lays over the radio switch, causing inadvertent radio frequency changes.
- The weapon select switch feels too similar to other switches.



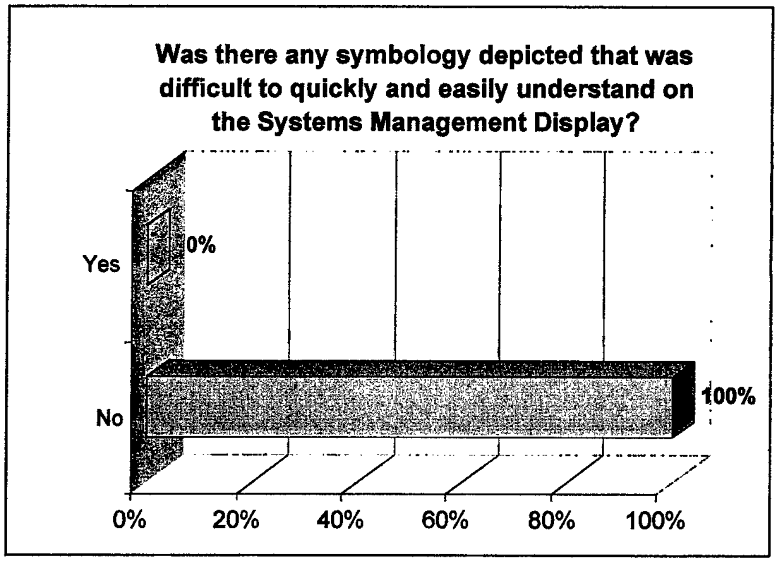
Pilot Comments:

- Do not like or find the utility of the forced assist switch (AFCS or Yaw Trim or Coupler Release). It is in an awkward position and not very useful.

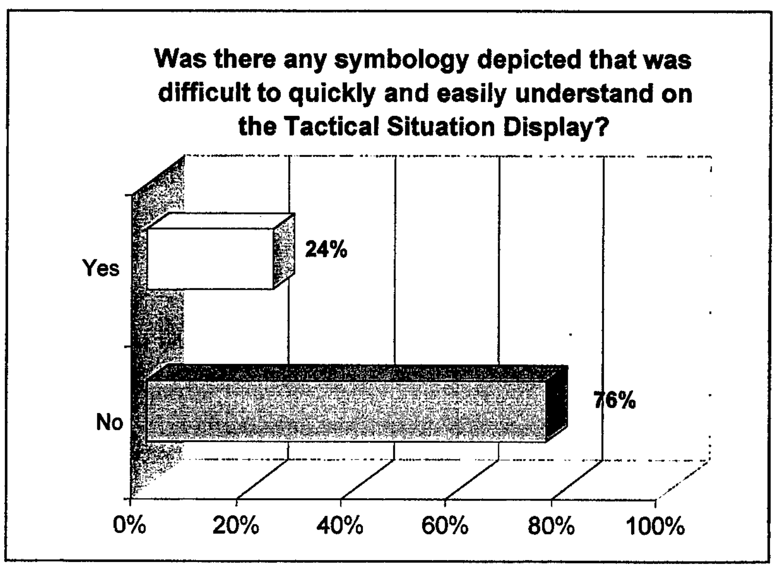


Problems With Moving Heading Tape (five comments)

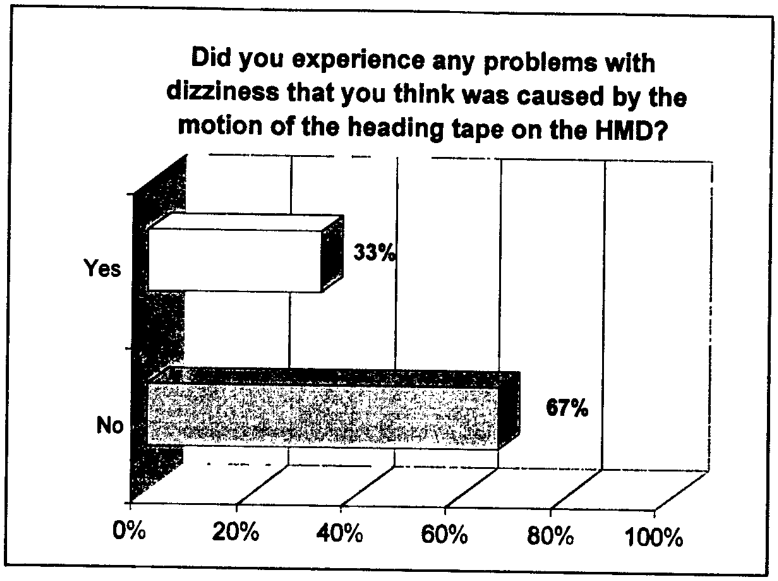
- Heading tape on HMD should be screen stabilized. It moves at odd angles.
- Heading tape geo-stabilized is disorienting.
- HMD heading tape should not move.
- The heading tape is not easy to use. It moves too much in different planes.
  - Heading tape is disorienting. Should be stabilized and not move with artificial horizon.



No comments.

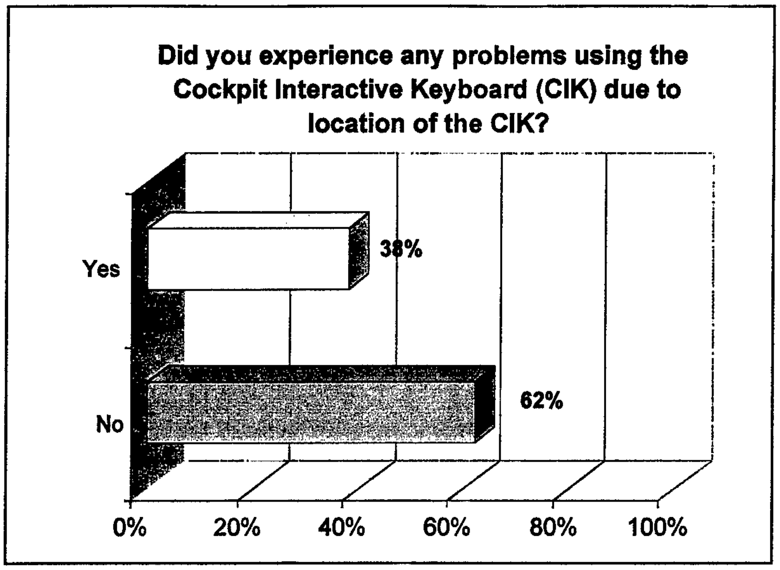


- TSD gridlines are not easy to read. Numbers are easily obscured.



Problems With Motion of Heading Tape (21 comments)

- It becomes very severe during rapid movements and degrades performance.
- The fact that the heading tape is geo-stabilized is disorienting.
- Not very severe because I have learned to ignore it.
- I ignore the heading tape though. I only use the boxed aircraft heading tape because it is not confusing.
- I usually ignore the heading tape when I'm not straight and level.
- No, However, heading tape is difficult to interpret when in a medium to tight bank angle. (Screen vs. geo. Stabilized)
- Not so much as dizziness, as just spatial disorientation. Heading tape should be screen stabilized.
- Not severe but while deploying to cover or actions on contact. It's hard to chase heading tape in the HIDSS.
- I ignore the heading tape now because it is confusing. I only use the boxed aircraft heading.
- When in steep turns or unusual attitudes, the reading tape becomes disorienting.
- No problems because I ignore it now and only use the boxed aircraft heading.
- May cause spatial disorientation.
- During aggressive maneuvers, the heading tape is disorienting.
- May cause spatial disorientation.
- When performing actions on contact, you do several turns and your heading tape is all over the place in the HMD. It's too hard to check the headings.
- Still ignore the heading tape. Only use the boxed aircraft heading tape.
- In turns, you lose some of the heading tape and it is disorienting.
- Causes spatial disorientation.
- Not severe, but after performing evasive maneuvers you need to quickly get your bearing.
- No, I ignore it usually.
  - When banking aircraft, you lose part of the heading tape and all the symbology movement is disorienting.

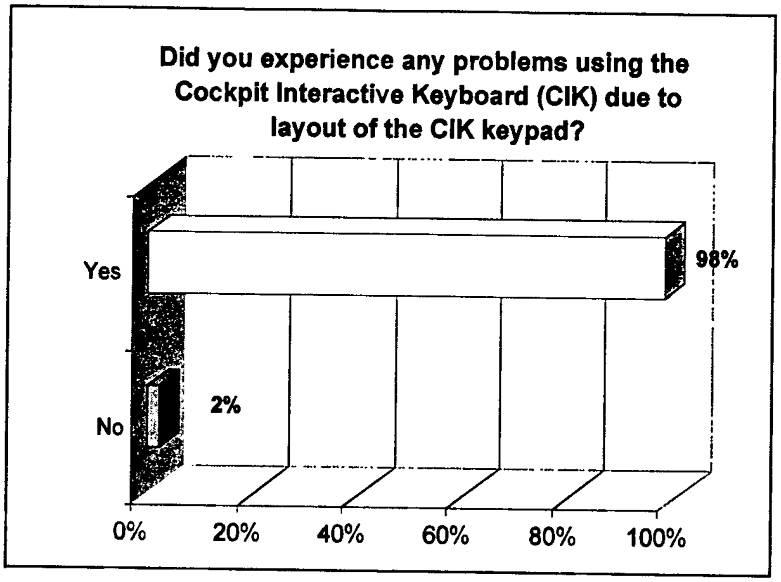


Problems With Location of CIK (11 comments)

- Data entry required me to lean too far forward. (3 comments).
- Lose SA entirely when looking down between legs.
- I don't like looking down for extended periods because I lose SA totally. And in an aircraft, you could experience spatial disorientation while your head is in a different plane than your body.
- I don't like looking down the whole time than I am typing. It should appear on the screen so I can still glance at the other screen.
- The front seat in CPC. The CIK won't extend when in a comfortable seating position.
- Don't like looking down.
- Forces user to look down and does not allow you to monitor MPDs and MFDs.
- Requires heads down operation too long. Lose ability to do anything else.
- Lose all SA while focusing all attention downward.

Other Problems (six comments)

- Layout of CIK is a problem.
  - Could not enter entries unless TSD was at home position (not have anything selected).
- Buttons too small. Layout not intuitive.
- Button too small, layout not efficient. Would prefer to a "QWERTY" layout.
  - Needs to have a down arrow key on CIK.
  - Is too slow, has no TAB function and should be a standard keyboard.



CIK Keyboard Layout Needs to be QWERTY (PC style) (eight comments)

- With flight gloves on, data entry is difficult and placement of keys is not efficient. Maybe a typewriter keyboard would be easier.
- If layout was QWERTY, I could type without looking and that would be very useful for SA. Also, free text messages should show text in SMD as inputted.
- Need a standard layout.
- A QWERTY format would allow typing without looking and be able to look around more.
- The keyboard should be in a "QWERTY" layout.
- QWERTY would be good so I can type without looking at keyboard.
- I can type quickly and would be nice to type on a QWERTY device. I would use DIG COMMS more often.
- Touch-typing would be much faster.

Need a TAB Function (six comments)

- Need a TAB function.
- We need a TAB key.
- The keyboard needs a tab-to-next-field function.
- Takes too long to scroll to next field of data (need a TAB key).
- Hit a few wrong keys trying to go fast, TAB key between fields.
- Entering messages in free text (via CIK) is very time-consuming and cumbersome. A TAB function would help.

Other Comments (11 comments)

- Errors in entering data. (All pilots had this problem for the majority of missions)
- Data entry required too much time. (All pilots had this problem for the majority of missions).
- Free text takes too long (via CIK) because you must press four buttons just to start entering messages. Very time-consuming.

- Would like data to go to SMD directly and be saved so you could come back to a message if necessary.
- Would like data to appear on SMD as I input it. Therefore, I can keep my head up and still maintain some SA.
- Required me to be "heads down" to long. Maintaining SA is difficult when heads down so long.
- Loss of situational awareness due to being involved in data entry on free text messages.
- Does not prompt user to required spaces.
- You have to push the buttons hard to make an entry.
- If when entering information, the system auto-filled information based on the type of data you are entering, this would increase pilot efficiency.
- Need a down arrow key to skip lines for data entry.

Were there any significant differences in the operation o the following components in the EDS versus the CPC?		
	Yes	No
Cockpit Interactive Keyboard	2%	98%
Multipurpose Displays	0%	100%
Systems Management Display	2%	98%
Tactical Situation Display	0%	100%
Tactical Interface Annunciator Panel	0%	100%
Head Mounted Display	0%	100%
Collective Grip	29%	71%
Sidearm Controller	0%	100%

<u>Radio Select Switch on Collective Grip</u> (13 comments)

- Radio switch positions are on different axis on Collective Grip.
- Radio select switches are 90 degrees out from each other.
- Radio tuning switch is different in each simulator making it extremely difficult to learn to use it efficiently.
- Radio select is opposite.
- Radio frequency switch is not identical in direction (of actuation) to perform functions.
- Radio select switches in the two cockpits are 90 degrees out from each other.
- The COMM switch axis of operation is different in the EDS vs. the CPC. Primarily used the switch in the back seat. The EDS COMM switch does not actuate forward/aft. It actuates off-center.
- Radio select switches are in different orientation from the EDS to the CPC.
- Radio switch actuates differently in the CPC vs. EDS.
- Radio select switches are different in EDS than CPC. Takes a little longer if you change radio frequencies by mistake.
- Radio select SW not positioned correctly in the EDS.
- Radio select switches are not positioned correctly in EDS.
- The comm. Switch on the hands on grip in the EDS has a rotated axis of activation than the CPC.

Other Differences (two comments)

- SMD COMM TUNE – Securing the UHF and VHF radios in the CPC (is a problem). After selecting KY and then pressing secure soft bezel, you have to off-tune the frequencies and come back for it to actually go green on the RMPD. Securing radios, you have to select KY variable (using the CIK is very difficult) before securing the radio. These add great time to the tasks at hand.
- CIK in the EDS has to have a warm up time in the back seat before anything can be entered.

List any other crew station usability features that hindered your performance during missions.

Pilot Comments:

- Remote Hellfire page is too 'busy'. Too much information to look through.
- TIAP/SMD functions that require user to focus on both TIAP/SMD are not user-friendly. User should only have to focus on one screen for the same task.
- Need to be able to send overlay messages to help change of mission planning.
- Radio control panel on left console needs more lighting.
- I think that the BDA report should assign a default status of destroyed since that is what I pick 95% of the time.
- I think I should be able to select a status with the slew hook rather than pushing a button on the TSD. It seems counter-productive to initiate the message with the slew hook, select STAT, push a button for status, and then go back to the slew hook to send the message.
- The TIAP doesn't display the target number associated with the fire mission when you call-for-fire. If you have multiple missions, it is easy to forget which mission is associated with which target.
- Cord to the ProView 50 needs a clamp to secure the cord to the user to prevent the device from moving during head movements.
- Some sort of off hand controller for operations of left and right slew hooks and EOTADS functions. Currently, crew member has to lean to the left wing panel with right hand for operation of systems and it becomes uncomfortable after a period of time.
- When wearing NBC gloves, the slew to own switch is too close to the radio select switch and the details button is too close to the no target switch.
- Volume of headset varies greatly in the CPC.

Appendix J. Summary of Switch Actuations

Switch Actuations	No.	Percent	Switch Actuations	No.	Percent
Communication System (Total)	**167,765**	**66**	**Target Acquisition System**	**56,571**	**22**
XMIT On	62092		No Target	12,300	
XMIT Off	61963		Find	5655	
Inbox	14218		Review	5639	
TSD Designate	11055		Field-of-View	4542	
Battle Damage Assessment	6920		TAS	4478	
Com Reports	3123		Zoom	3113	
Next Radio Xmit	1315		Line-of-Sight Select	2480	
Recon-Spot	1186		Continuous On	2442	
Previous Radio Xmit	896		Target	2333	
TIAP	722		Scan	2186	
Call For Fire	557		Field-of-View Change	1950	
Recon-Situation Report	445		Slave On	1812	
Preset	435		Slave Off	1812	
Free Text	421		Label Targets	1035	
Com FS	294		Auto Track System	972	
Recon	271		Scan Mode	867	
Arty	223		Continuous Off	696	
Del-Save	213		Laser On	434	
Situation Report	185		Laser Off	433	
Transponder	146		HTS Slave On	337	
Message Bar	139		HTS Slave Off	337	
Spot	134		Setup	330	
Next Preset	126		Point-of-Interest	178	
Previous Preset	110		Next Track	87	
Army Aviation -Remote	87		Previous Track	51	
Forward	72		Image Auto Track	39	
Com Tune	60		Sensor	21	
Army Aviation: BDA	54		Polarity	6	
Configure	42		Aim	6	
Return	36				
Next Radio	33				
Radio	29				
XMIT	28				
Next	26				
Security	21				
Previous	20				
Army Aviation -Handover	15				
Army Aviation	14				
Army Aviation: Target	12				
Army Aviation: Return	9				
Move Display	7				
Blank	3				
Message List	3				
Previous Radio	3				
Frequency Key	1				
Select	1				

Switch Actuations	No.	Percent
TSD Functions (Total)	**13,224**	**5**
Home	9906	
Tool	854	
Overlay	801	
Configure	756	
Image Configure	393	
View	266	
Window	183	
HMD Mode	42	
Slave HRD1	22	
Update	1	
Map Functions (Total)	**6092**	**2**
Map Switch Down	2854	
Map Switch Up	2814	
Map Detail	424	
Weapons Functions (Total)	**3932**	**1.5**
Detent 1	847	
Trigger Guard Down	529	
Trigger Release	522	
Trigger Guard Up	521	
Detent 2	482	
Missile Switch	328	
Missile Main	256	
Gun	216	
Gun Switch	139	
Master Arm	65	
Laser Mode	27	
SMD Functions (Total)	**2915**	**1**
Slave HRD2	1877	
SMD Designate	1038	
Navigation Functions (Total)	**1844**	**.7**
NAV Current	923	
NAV Plan	921	
Engine Instruments (Total)	**795**	**.3**
Engine Instruments: Comm	437	
Engine Instruments	353	
Engine Instruments: Move	5	

Switch Actuations	No.	Percent
Cockpit Interactive Keyboard (CIK) (Total)	**579**	**.2**
Enter	579	
Aircraft Survivability Equipment (ASE) (Total)	**422**	**.2**
ASE Engage	304	
ASE Comm FS	101	
ASE Next	17	
System Configuration Functions (Total)	**316**	**.1**
Alarms	106	
System Configure	98	
Preferences	39	
System Config: Nav	36	
Status	17	
Sensors	14	
Combat	6	
Flight Instruments (Total)	**178**	**<.1**
Flight Instruments	178	
Warnings-Cautions-Advisories (WCA) (Total)	**94**	**<.1**
WCA	94	
Right Multipurpose Display (RMPD) (Total)	**77**	**<.1**
Alternate Switch #2	77	
Flight Control Functions (Total)	**68**	**<.1**
Altitude Hold	49	
Velocity Stabilization	19	
Aircraft Start-up (Total)	**28**	**<.1**
Start Off	15	
Ignition Auto	8	
Ignition Off	5	
Other Switches (Total)	**81**	**<.1**
Alt	59	
Landing Gear Switch	18	
No RMAD	2	
Primary Fire Bottle	2	

Appendix K. Summary of Crew Situation Awareness Comments

List any instances when you had low situational awareness.

Front Seat

Problems With Maintaining Situation Awareness Due to Size of Map Scale-TSD (six comments)

- When repositioning aircraft, it is difficult to maintain awareness of TSD map. Did not have good awareness of where targets were when they were outside TSD screen.
- When in 7.2K scale map on TSD, I could not see relation of my aircraft to my sister aircraft and targets.
- Had low SA when flipping thru map scales. On 18K map scale, you lose terrain detail but get broader view of area. On 7.2K map scale, you get more terrain detail but lose broader view of area.
- When performing evasive maneuvers, I lose SA while making rapid 90 degree turns. It's easy to regain SA with map, but would be even better if control measures and enemy within 10 km would be displayed on the 36 km scale.
- When my TSD is in a larger scale, I lost SA of Holding Area, Tactical Assembly Area, and the route.
- When in 7.2K scale on TSD, I lost SA relative to position in the zone and relative to sister aircraft.

Low Situation Awareness When Engaged by the Threat (five comments)

- When being engaged by enemy, I lose SA of where the enemy is engaging me from.
- When engaged by threat, could not determine where the fire was coming from and where I needed to go to deploy to cover.
- Had low SA when being lased by BMP. The ASE warning gives mag degrees heading instead of clock position. Would help to react quicker to threat if ASE warning was clock position (i.e., "laser 2 o'clock").
- When we were being shot, the screen blanks (goes red) and the pilot loses all SA relative to the ground.
- Had low SA when being shot at.

Other Problems (14 comments)

- Not having AMPS makes pre data entry and mission planning difficult (i.e., routes and speeds). Airspeeds should update to assume all after selected waypoint unless locked.
- Route Crow was picked by someone else. We had no AMPS to check intervisibility of route.
- When flying formation, lost awareness of location of route. Was concentrating too much on formation.
- The EDS radios volume was too low. It was very hard to understand the crew in the CPC.
- Low SA was due to ATCOM failure.

- When looking down to input free text messages via the CIK, I did not have good situational awareness.
- On take-off, 2S6's were searching from convoy. We were not briefed of host nation vehicles within our convoy.
- When I was inside the cockpit inputting a free text message in the CIK, I wasn't able to look out for an extended period and had low SA.
- The graphics are a little ambiguous. Difficult to maneuver along a ridgeline NOE due to marginal depth perception.
- At the very start of the mission, I didn't have time to look at TSD map to get idea of where I was and where I needed to go. I have very low situational awareness.
- Would prefer a clock position instead of a compass heading from the warning system.
- While flying NOE altitudes, it is very hard to conduct ground observations to clear around the aircraft.
- When we were busy, I couldn't keep slewing down to see when the wingman was engaging, so I only had SA for my sector most of the time.
- Only when I did not check messages and I was using TAS or flying and the back seater did not fully explain what the messages said.

Back Seat

Low Situation Awareness When Using the TSD (eight comments)

- When targets get displaced on the TSD, then it becomes confusing because when it sees them again, it has new icons. So you think that the enemy has doubled in size when it is the same vehicles seen twice.
- Low SA when using TSD. Remembering to press "TSD Home" after any cursor input is cumbersome. Also, when in a large scale (on the map), I lost SA of the surrounding elements.
- When zoomed in on the TSD, I lost awareness of targets and route.
- Had low SA frequently during the mission. Could not maintain SA while in 7.2 km scale. But if zoomed out, you lose terrain detail. When AMC, it hampers ability to fight and maintain SA of battlefield.
- When dispositioning targets and front seater repositioned the aircraft, I lost situational awareness on the TSD map. I had to come out to different scale to re-orient myself.
- When zoomed in on TSD enough to see terrain features, I lost situational awareness with other targets and wingman.
- Had low SA when I scrolled down in map scale and pilot performs evasive maneuvers. By the time you scale up, it takes a few seconds to get your bearing.
- I had difficulty maintaining SA with other aircraft when they were not close to our aircraft. When battlefield is spread out, it is difficult to keep slewing around to look for targets and change map scales.

Low Situation Awareness Due to Lack of Night Vision Device (seven comments)

- As MEPO, you have no aircraft SA due to lack of I2 device.
- Had no SA of aircraft outside position because I did not have I2.
- I had no situational awareness of what the aircraft flight profile was. I was too busy to come up BUPS to get a look around the aircraft. The aircraft needs an IRII system for the back seater to gain SA of aircraft.
- Slow SA when we were avoiding a target and I could not see outside to engage it and help the pilot maneuver.
- As the MEPO, you have virtually no SA of what the aircraft is doing. I2 would help a lot.
- As backseater, you have no SA without using TAS BUPS.
- Without I2, the MEPO has no aircraft SA (at night).

Other Problems (11 comments)

- Had low SA when creating text messages because it is a time-consuming task.
- Had low SA when managing messages.
- On complex missions with multiple threat, it is easier to keep SA when TSD is oriented 360 degrees at all times rather than track.
- Only when searching for a target that moved while I was masked.
- Without radar, I did not have good security around the aircraft at all times.
- At one point, we had three 2S6's searching our area, but in order for us to get eyes on the route we were reconning, we had to come up in altitude over mountains.
- When we were traveling near towers and the front seater was having difficulty controlling the aircraft, I could not see out except with TAS. So, I could not help with obstacle avoidance.
- It took a long time to get a fix on the last BMP because he was up in the mountains. I think I should have adjusted my radar to look more down so that it would pick him up faster and help me find him sooner.
- Had low SA only when wingman was engaging dismounted troops. I did not know how long he was taking.
- When engaging multiple targets, I could not read messages so I had no idea on the data flow from higher HQ.
- On takeoff for a brief instance, I was not aware Chalk 2 had not left the assembly area with us.

Acronym List

AAR	after-action review
AFCS	automated flight control system
AMC	air mission commander
ARL	Army Research Laboratory
ASE	aircraft survivability equipment
ATCOM	advanced tactical combat
ATD-C	aided target detection-classification
ATM	aircrew training manual
AWS	area weapon system
BDA	battle damage assessment
BUPS	back-up pilotage system
BWRS	Bedford Workload Rating Scale
CIK	cockpit interactive keyboard
CPC	Comanche portable cockpit
CW2	Chief Warrant Officer, W-2
EDS	engineering development simulator
EOTADS	electro-optic target acquisition and designation system
DTV	day television
FARP	forward arming and refueling point
FDE 1	Force Development Experiment 1
FDTE 1	Force Development Test and Experimentation 1
FFE	fire for effect
FLIR	forward looking infrared
FMS 1	Full Mission Simulation 1
FOV	field of view
FRAGO	fragmentary order
HIDSS	helmet integrated display sighting system
HOG	hands-on grip
HMD	helmet- or head-mounted display

HTS	helmet tracking system
I2	image intensification
IMC	instrument meteorological conditions
IR	infrared
LMPD	left multipurpose display
MANPRINT	manpower and personnel integration
MEP	mission equipment package
MOP	measures of performance
MOPP	mission-oriented protective posture
MPD	multipurpose display
NBC	nuclear, biological, chemical
OMS-MP	operational mode summary-mission profile
OTW	out the window
POI	point of interest
PTWS	point target weapon system
RAH-66	reconnaissance attack helicopter
RCS	radar cross section
RMPD	right multipurpose display
SA	situation awareness
SAL	semi-active laser
SART	Situation Awareness Rating Technique
SAC	side-arm controller
SMD	system management display
SME	subject matter expert
SSQ	Simulator Sickness Questionnaire
TAS	target acquisition system
TIAP	tactical interactive annunciator panel
TRADOC	Training and Doctrine Command
TSC	tactical steering committee
TSD	tactical situation display
TSM-C	TRADOC System Manager-Comanche
TTP	tactics, techniques, and procedures

USAOTC	United States Army Operational Test Command
VMC	visual meteorological conditions
WBGT	wet bulb globe temperature
WCA	warning, caution, advisory
WSRT	Wilcoxon Signed Ranks Test
XMIT	transmit

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